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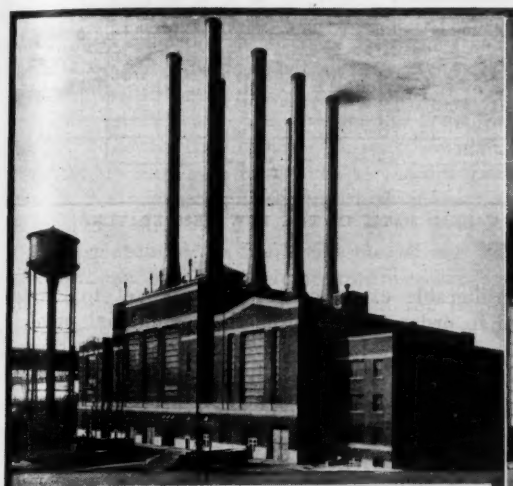
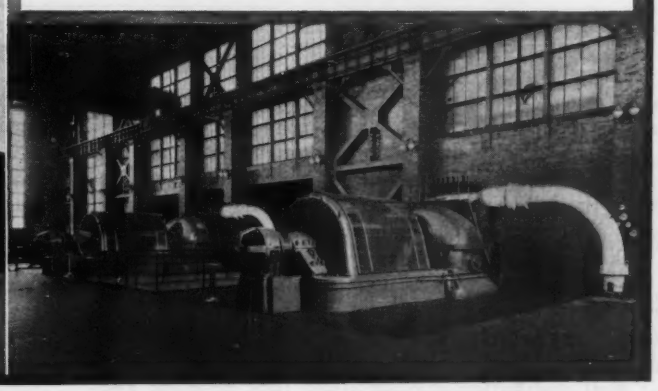


LOW TEMPERATURE DISTILLATION OF COAL TO FURNISH THE COKE SUPPLY

Ford Plants to Use Pulverized Coke



AT THE TIME the River Rouge power plant of the Ford Motor Co. was placed in operation in 1920, it attracted wide-spread attention among engineers because of the many unusual features. The boilers installed were out of the ordinary, both because of their size and because they were designed for the use of pulverized coal and gas as fuel. Another problem which had to be met was the supplying of evaporated make-up for boiler feed to the extent of 20 per cent of the total water used.

Once more this plant is holding the interest not only on account of the fact that plans call for the addition of 230,000 kw. in generator capacity, which will make it one of the largest industrial power plants in the world, but also because the problem of securing an adequate and cheap fuel supply is being approached from an entirely new angle.

Low temperature distillation of coal, which is a process never previously utilized in a commercial way, will form the basis of the new fuel supply. Coal will be brought from the Ford mines in Kentucky, will be put through the low temperature coking process, certain of the by-products recovered and the coke will be pulverized and used as fuel in the power plant.

It is also planned to use this general scheme at the power plant now being constructed for the Canadian Division of the Ford Motor Co., at Ford, Ontario.

Behind the decision of the Ford organization to go into this rather radical approach to a solution of the fuel problem lie two main thoughts. First, Mr. Ford's belief in the full utilization of resources and, second, the necessity for assuring an adequate fuel supply to guard against a plant shut down such as occurred during the last coal strike.

In order to have a proper understanding of the conservation factor which enters into the process of low temperature distillation, it is necessary to understand, in a general way, the characteristics of coking coals.

In the ordinary coking process, where the coal charge is placed in a closed oven and heated, the prime requisite is that the coal must shrink during distillation, so that the coke can be pushed out of the oven. Low volatile coal is usually a non-shrinking coal, while high volatile coals tend to shrink more than low volatile coals. High volatile coals are not used alone because they generally make an inferior grade of foundry and blast furnace coke. In other words, high volatile coal is generally not suitable for use in making furnace and foundry coke and the number of shrinking low-volatile coals is limited.

Besides the fact that there are more high volatile coals available than low volatiles, there are other economic reasons favoring the use of a low temperature distillation process. The primary object in coking coal for boiler fuel is not for the purpose of making fuel but to recover the by-products which are otherwise largely wasted. The coke may also be used for a number of purposes. It may be briquetted into a smokeless domestic fuel of anthracite character; it may be pulverized and burned in furnaces; it may be ground and mixed with high-volatile coal for the purpose of making

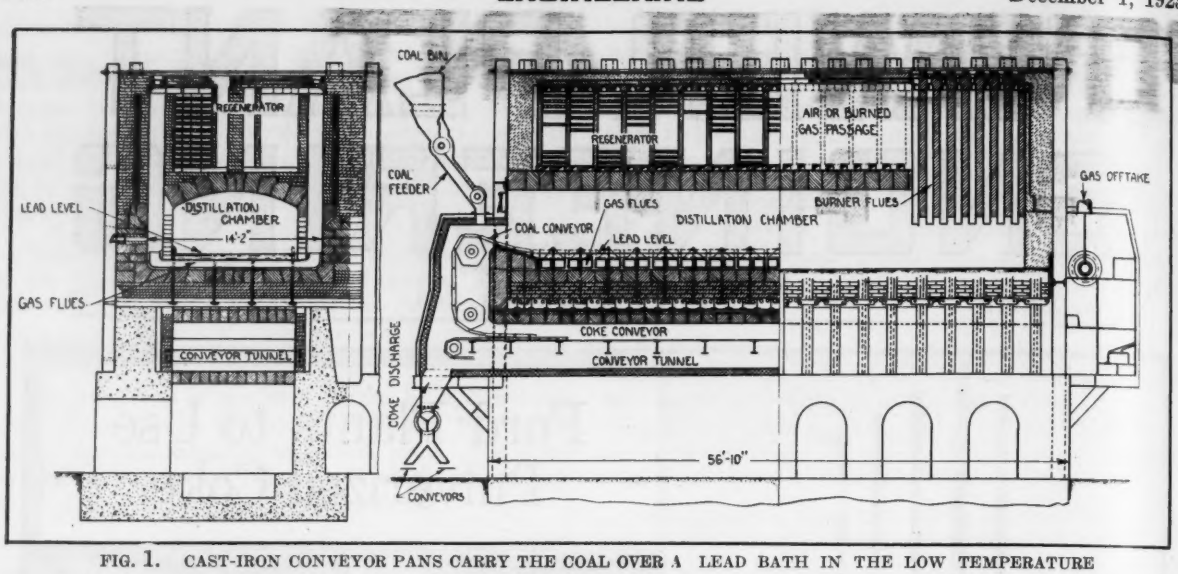


FIG. 1. CAST-IRON CONVEYOR PANS CARRY THE COAL OVER A LEAD BATH IN THE LOW TEMPERATURE DISTILLATION PROCESS

metallurgical coke or it may be burned directly on chain grate stokers.

Of these possible uses the two most important as far as the Ford organization is concerned are the use of this coke in the pulverized form as fuel for the power plant and as a mixture with high-volatile coal for the purpose of making metallurgical coke.

In addition the by-products form an important factor in utilizing this scheme. These by-products have different characteristics than those obtained by the high temperature distillation process. This is due to the fact that coal distillation divided itself into primary and secondary distillation products. Up to about 1380 deg. F. the primary distillation takes place and if the gases are condensed before reaching a higher temperature the by-products are entirely different from those produced at higher temperatures.

With the high temperature process the gases distilled off at first are still further broken up into secondary products. The actual recovery of specific by-products then depends upon the method of treatment and the temperatures used.

FIG. 2. SECONDARY AIR ENTERS THE BOILER FURNACES THROUGH THESE DOORS

Considerable experimental work is yet to be performed in order to determine the commercial possibilities in these low-temperature by-products, although from preliminary work done it is expected that the following products will be obtained from a ton of coal:

1. 1500 lb. of coke.
2. 7000 cu. ft. of 700 B. t. u. gas.
3. 5 gal. motor fuel stripped from gas.
4. 20 lb. sulphate of ammonia from gas and condensation liquor.
5. 25 to 30 gal. of very light tar of a crude oil like character.

Just what a further treatment of the tar will yield is a matter for experimental work, although present data show that this tar will yield some 5 gal. of motor fuel, 2½ to 3½ gal. creosote oil, 1½ to 2½ gal. lubricating oils and 8 to 12 lb. of lubricating grease. After recovering these products from the tar a heavy oil of tar-like character will remain which may be used as fuel oil.

In order to carry out this low temperature distillation scheme two ovens, which will have a capacity of 500 T. each per 24 hr., are now in the course of erection. Ultimately it is expected that eight of these ovens will be in operation.

Described in its simplest terms, it might be said that these ovens are made up of a molten lead bath in which float cast-iron pan conveyors.

In Fig. 1 is shown the detailed arrangement for one of these ovens. It consists of a clay refractory furnace having two longitudinal arched chambers, provided with curtain walls at each side to separate the heating and exhaust chambers from the distillation space. Cast-iron U-shaped flues in twin form connect the heating and exhaust chambers, the lower section of the flues being completely submerged in a bath of molten lead. These U-flues provide heating-gas passages under the entire lead surface.

Each chamber is provided with a conveyor system made up of three strands of cast-iron plates. These plates are 1 in. thick, with flanged ends, the hinges and pins being placed low enough to make a flat, unobstructed surface to receive the incoming coal. On their

return to the furnace proper, the conveyors are supported by a series of rollers resting on rails. As will be noted from Fig. 1, these rollers carry a secondary conveyor system.

When the coal has passed through the lead bath and has been raised to a temperature of about 1200 deg F., it then falls onto the secondary conveyor and passes back through the furnace. As the plates of the main conveyor are just above the hot coke on the secondary conveyor the temperature of the main conveyor plates is maintained nearly constant on the return to the lead bath. Another advantage in passing the coke back through the furnace is that the extra time in the hot gaseous atmosphere of the furnace frees the treated coal of unstable gas but does not reduce the capacity of the direct heated upper portion of the oven.

Waste gases leave the U-flues at a temperature slightly above the 1200 deg. F. temperature maintained in the bath. This heat is not lost as the hot gases pass through the recuperator section which is used to heat the incoming air.

Having secured an idea of some of the economic considerations of the low-temperature coking method and more especially those relating to the recovery of the by-products, the next point of interest is a study of how the scheme will aid in assuring against a shutdown of the plant. This question of coal supply concerns not only the power plant alone, but also the blast furnaces.

As previously mentioned, the production of metallurgical coke requires a low volatile shrinking coal. Considering that this kind of coal is not as plentiful as other kinds which may be used for power purposes, it is evident that the securing of an adequate coal supply

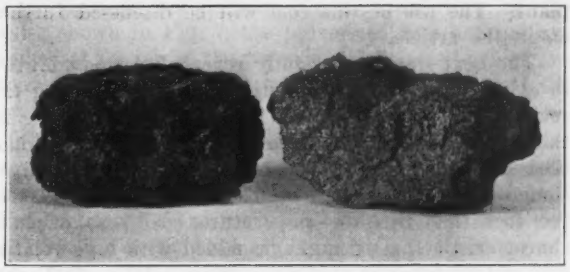


FIG. 3. LOW TEMPERATURE COKE IS BLACK AND QUITE POROUS IN STRUCTURE

On the left is a sample of low temperature coke as compared with metallurgical coke on the right. Low temperature coke weighs 19¾ lb. per cu. ft.

during the last coal strike was a serious problem. In fact, a solution of this problem was considered so important that the management was ready to take hold of anything which offered a ray of hope.

One of the first steps was the acquirement of still further mining properties in Kentucky and West Virginia which offered high and low volatile coals of a type suited to the requirements of both the power plant and for making coke. At the same time, transportation could be taken care of over the Detroit, Toledo and Ironton Railroad which is owned by the Ford organization.

An investigation of the coal supply also revealed large amounts of laminated or bone coal available in the Kentucky field; coal which contained so much slate that it had been discarded at the mine. As the only cost for this coal was largely a question of handling a scheme was worked out to utilize such coal in the power

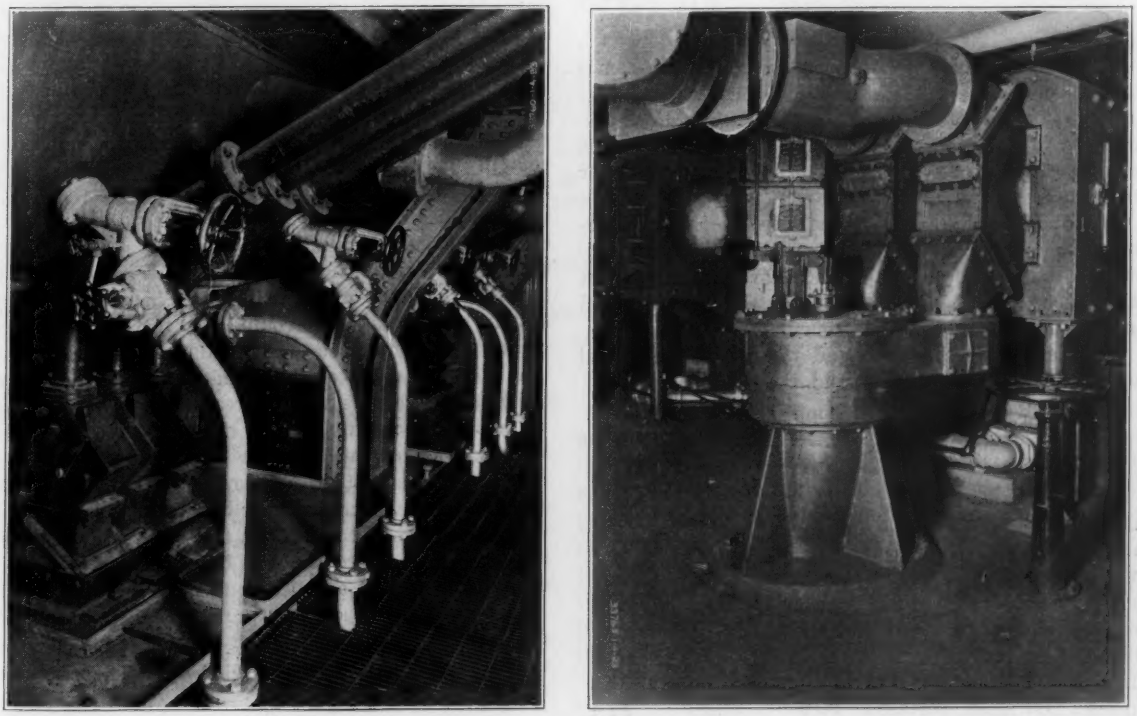


FIG. 4. FURNACES ARE EQUIPPED WITH PULVERIZED COAL AND GAS BURNERS

On the left is a view of the triplex pulverized coal burners. There are four of these burners for each boiler and each triplex burner has three feed pipes. Each boiler has two gas burners such as shown in the view on the right. The location of these burners may be seen in Fig. 7. Ordinarily blast furnace gas is used, although when there is surplus coke-oven gas that is burned.

plant. The use of this coal will be discussed further on in the article.

The next step in the study revealed the possibilities in a low-temperature distillation scheme and using the coke in pulverized form as fuel. The use of coke in this way was not a new idea as metallurgical coke had occasionally been used in the boiler furnaces at the River Rouge plant. One point which offered an appeal was the fact that the low-temperature coke was of such characteristic that it might be mixed with high-volatile coal and the mixture used for making metallurgical coke.

After considering these factors it was decided to take up the low-temperature distillation process and apply it on a commercial scale.

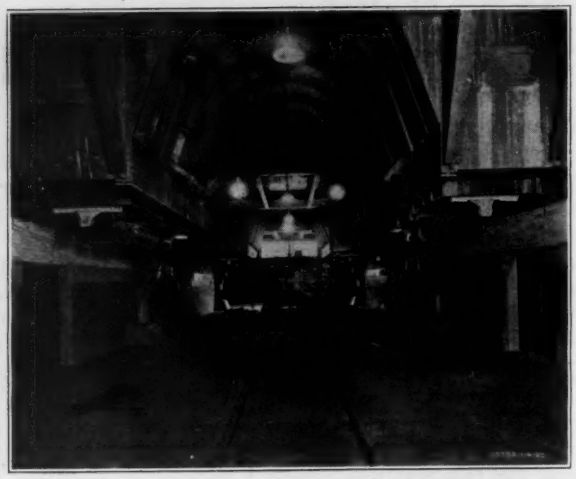


FIG. 5. SLAG IS TAKEN OUT THROUGH THE POWER OPERATED ASH GATES AND IS LOADED INTO STANDARD RAILWAY CARS

Coal which is used by the Ford organization comes from Kentucky and West Virginia. The Kentucky coal is high volatile; that coming from the Banner Fork district running about 38 per cent. The West Virginia coal comes from Twin Branch and shows about 19 per cent volatile matter.

In order to secure an idea of how the low-temperature coke would burn in pulverized form an experimental oven was used to produce several carloads of coke which was then sent through the regular coal handling and pulverizing equipment.

An analysis of this coke and the Pond Creek coal from which it was made showed the following:

	Pond Creek Coal	Low-Temperature Coke	Bone Coal
B. t. u.	13,600	13,250	11,630
Sulphur, per cent	.67	.41	1.50
Carbon, per cent	58.3	70.6	48.40
Volatile, per cent	31.3	13.6	28.50
Ash, per cent	8.8	10.1	21.50
Moisture, green, per cent	1.60	6.9*	3.40
Moisture, pulv., per cent	1.40	5.7	1.60
Through 100 mesh, per cent	80.0	97.80	91.8
Through 200 mesh, per cent	90.0	56.90	81.4

No difficulty was experienced in burning the low-temperature coke and it seemed to ignite fully as well as pulverized bituminous coal. Some difficulty may be experienced in wear on the pulverizing mills as the coke has more of an abrasive action than coal.

As previously mentioned, bone coal is used in the Rouge plant. This coal, as will be noted from the analysis, contains over 20 per cent ash and a high sulphur content. Quite naturally it would appear that such a coal would have little value as a power plant fuel.

It is used, however, at the Rouge plant by mixing it with the better grades of Pond Creek coal. At first an attempt was made to use 50 per cent of each but it was found that slagging increased to such an extent that the boilers had to be taken out of service at least every 3 months. Since it is the practice to run a boiler 6 months before taking it off the line for an overhauling, the amount of bone coal used was cut down to a point where it was possible to get the required length of service. It was found that 25 per cent of the bone coal and 75 per cent of the better grade gave good results.

The coal is mixed at the time it is dumped. One car of the refuse coal is dumped with three cars of regular Pond Creek coal. Mixture of the two grades is secured during the crushing and pulverizing operations.

Green coal is delivered in standard coal cars and dumped by a rotary car dumper capable of handling a maximum of 1000 T. per hr. From the hoppers at the car dump the coal is conveyed by a 48-in. belt to two Bradford breakers. Any coal which does not break is passed to a picking belt and through a crusher. The quantity so handled is very small totaling about 5 T. for every 300 T. handled.

From the breakers the coal is carried by a belt conveyor at the end of which it passes over a magnetic pulley, to separate out any tramp iron, and is dropped into bunkers of 700 T. capacity in the pulverizer building. The coal passes through chutes to 12 Raymond pulverizing mills.

At one time all coal which contained a moisture content of over 3 per cent was passed through dryers, but this has been discontinued. The moisture content varies from 1½ to 5½ per cent in summer, although it sometimes gets as high as 8½ per cent in winter. It has been found that coal with a moisture content above 4 per cent causes some trouble. The mill capacity is cut down from 6 T. to 4 T. per hr. with a moisture content of 6 per cent. The screw conveyor system also gives some trouble due to filling up on the sides. Another place where difficulty is experienced is in the dust collectors. The moisture fills the pores of the cloth and causes a back pressure on the cyclones.

In future designs such as the plant now being built by the Ford organization at Ford City, Ontario, the pulverized fuel (low-temperature coke) will pass directly from the mills to the boilers, as this equipment will be located directly above the boilers. In this way, it is expected to reduce the trouble caused when excessive moisture is encountered.

After this coal has been pulverized in the mills, it is drawn out by exhausters and discharged into cyclone collectors, where the air is separated and returned to the mills.

As will be noted from the views shown in Fig. 6, excess air passes out through the tubular dust bags. These bags are the ones previously referred to in connection with one source of trouble due to moisture in the coal.

*Moisture from exposure in shipping.

From the cyclone collectors the pulverized coal drops into four 16-in. spiral screw conveyors which discharge into four bucket elevators. These elevators hoist the coal to an elevation of 209 ft. and discharge it into two 16-in. spiral screw conveyors which carry it across a bridge to the bunkers in the power house. Here the coal is discharged by means of four 16-in. cross screw conveyors into twelve 60 and 120-T. storage bunkers.

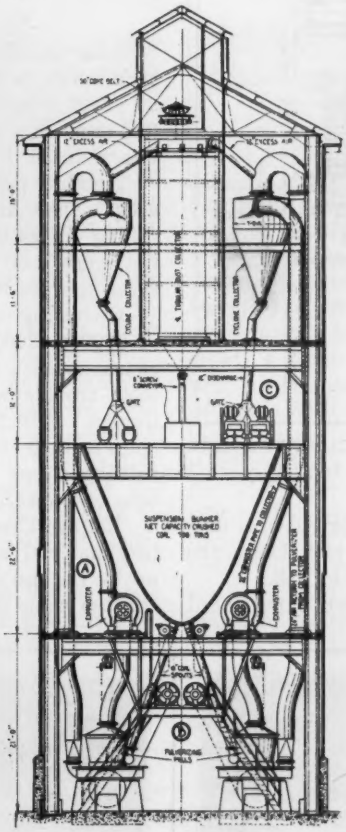
From the bunkers the coal is delivered to the furnaces by the feeders and triplex burners. The feeder screws discharge the coal into six 3½-in. pipes from each bunker, aided by an induced air pressure of 8 in. from a pressure blower.

As will be noted from the sectional view of the boiler shown in Fig. 7, the pulverized fuel burners are located at the top of the furnace and the gas burners are located in a dutch oven setting at the lower part of the combustion space.

The Lopulco burners are of the triplex type consisting of three rectangular chambers surrounded on four sides by air ports. Through the center of each inner chamber is a 3½-in. fuel nozzle which terminates 9¾ in. from the outlet, thus giving the mixture a chance to expand just prior to its emergence into the furnace.

A. Exhauster fans take the pulverized coal from the mills and pass it to the cyclones. The view shown in the photograph corresponds to location marked "A" in the cross section of the pulverizer plant.

B. There are 12 Raymond mills all of which are equipped with automatic feed regulators. These mills contain rollers which are mounted in pendulum fashion from a central rotating disk, so that centrifugal force throws the rollers out against the inner surface of a stationary annular ring.



C. These screw conveyors take the pulverized coal as it comes from the cyclones and dust bags and carry it to bucket elevators which elevate it to the top of the pulverizer where the coal is again picked up by spiral conveyors which take it to the boiler house bunkers.

D. This view is not shown in the cross-section of pulverizer plant as it shows the coal feeders above the boilers. Each feeder consists of a cast-iron hopper at the bottom of which are mounted three cast-iron screws of coarse pitch.

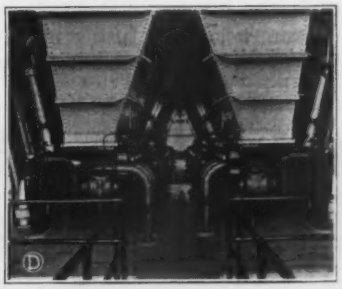


FIG. 6. PULVERIZED COKE WILL BE HANDLED WITH THE EQUIPMENT NOW USED FOR COAL

Considering the pulverized coal installation in its entirety, there are a number of features which stand out as unusual. The first is the elimination of the dryers in the pulverizing plant; second, the interlocking push button electrical control which makes it impossible to start one conveyor until the conveyor or elevator into which it feeds is in motion and which makes it impossible to start the pulverizers until all conveyors and elevators are in motion; third, the burning of such a wide variety of fuels and combination of fuels.

At various times the plant has used fuel oil, pulverized coal, pulverized coke, blast furnace gas, coke oven gas and tar in various combinations.

About 10 per cent of the air for combustion enters with the coal as the carrying medium from the feeder. The remainder of combustion air enters through the air ports in the burner and through the auxiliary air openings in the front of the furnace. Admission of the secondary air is controlled by the stack damper and not by the auxiliary air inlet covers unless the change of rating is wide. Ordinarily the rating is changed by varying the coal feed and the opening of the stock damper. If, however, the change in rating is, say, from 150 per cent to 250 per cent, the auxiliary inlet doors are set to secure the best operating conditions.

This auxiliary air is admitted at the bottom points to prevent impingement of flame and localization of excessive temperatures, thus protecting the brickwork

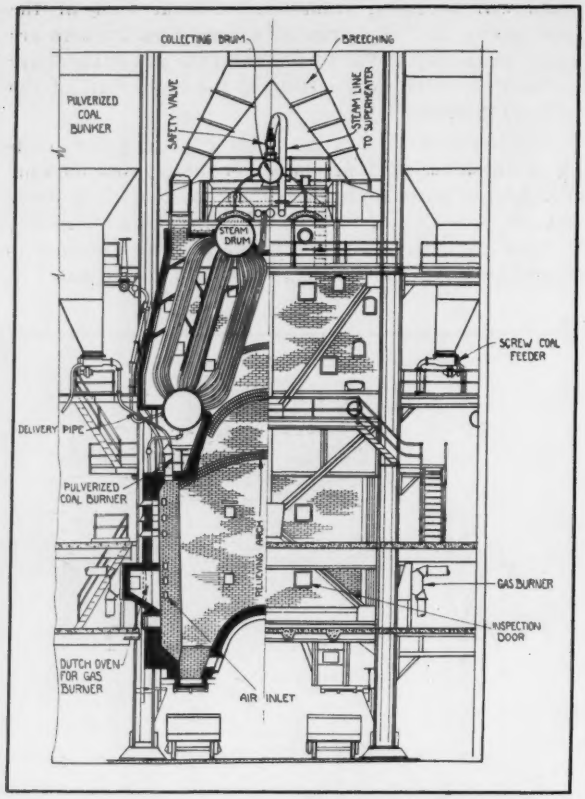


FIG. 7. BOILERS ARE RATED AT 2640 HP. EACH, BUT HAVE DEVELOPED AS HIGH AS 11,000 HP.

from erosion. At the same time a cooling effect is produced at the bottom of the furnace which keeps the temperature below the fusing point of the ash.

While some minor troubles have been experienced with the furnaces, these have been overcome by slight changes in the design. For instance the secondary air is introduced through ports which are set in what might be called a bay window jutting out in the furnace. This construction will be noted in the sectional view of the boiler, shown in Fig. 7 and the furnace view of Fig. 8.

It was found, however, that this bay window tended to reflect the heat to the side walls causing the localization temperatures which it had been expected would be eliminated by the air currents being directed toward the side walls. The new boiler settings have therefore been designed with a straight front but with the same relative location of air ports.

No Serious Furnace Troubles

Some trouble was also experienced with the suspended arch which is located at the burner entrance, as will be noted from Fig. 7. By rounding off the corner of this arch, through the use of special blocks, the spalling was reduced to a minimum.

Another point of trouble was in the first relieving arch. These arches failed due to the first two courses falling out as shown in Fig. 8. As originally designed, ties were used every six courses but by tying every three courses the trouble was corrected.

Operating as these furnaces do, at temperatures of 2000 to 2200 deg. F. and with a fuel with as poor characteristics as bone coal, it might be assumed that some trouble would be encountered with the furnace linings. The fact that it has been found possible to operate these boilers for 6 months' period with overhauling shows, however, that such difficulties as have been encountered are not serious.

Empire Crown No. 1 grade fire brick is the refractory material used for lining the furnaces and is backed up by the use of second grade brick. Once a year the furnace walls are covered with a commercial high tem-

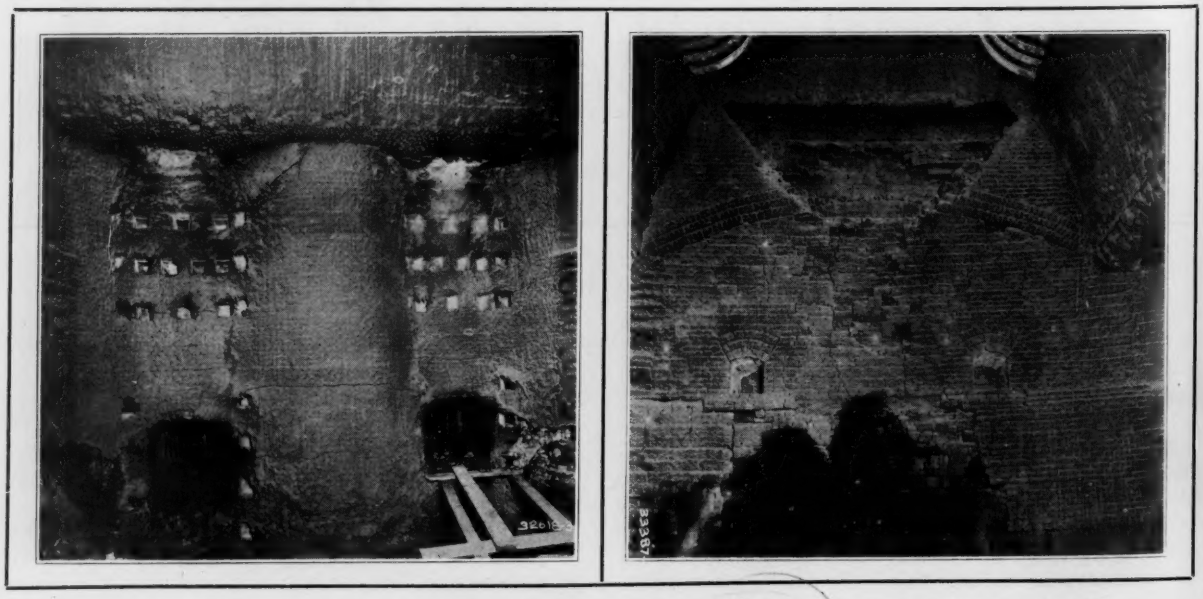


FIG. 8. ALTHOUGH FURNACE TEMPERATURES RANGE AROUND 2200 DEG. F., NO SERIOUS OPERATING TROUBLES HAVE BEEN EXPERIENCED

At the left is a view looking toward the front wall. The small square openings are the secondary air inlets. In the roof of the furnace may be seen the pulverized fuel burner openings and the two large openings at the bottom are the gas burners. In the new settings the bay window effect has been eliminated. At the right is shown a relieving arch failure which was due to lack of sufficient ties.

perature cement which is put on 3/8 in. thick by means of a cement gun. When the slag is removed at 6 mo. periods the high temperature cement lining comes with it and so it is renewed at such places. Figure 8 illustrates the condition of the wall after the slag has been removed.

No difficulties have been encountered with the baffles. These are made up of Ladd baffle tiles laid between the tubes and set up with fire clay. The original baffles, now in operation 2½ yr., are still intact.

Soot blowers are used for cleaning out the soot deposits on the tubes. These blowers are operated by each watch, or three times in 24 hr. It has been found that the flue gas temperature is reduced 10 to 15 deg. after each blowing.

While it is not the purpose of this article to go into an extended description of the plant, a few of the principal points are mentioned to give an idea of the equipment. As originally built the generator capacity was made up of two 12,500-kw. units. The boiler room has already been enlarged and work is now progressing on the installation of two 30,000-kw. units. According to present plans there will be eight of these units all of which will be built by the Ford organization at the River Rouge plant. The work will also include the building of condensers and circulating pumps.

This decision to build the equipment at the River Rouge plant is no reflection on the quality of equipment available, but was due mainly to the question of delivery dates. After the decision was made to make the River Rouge power plant the producing center for operations in Detroit the work has been pushed forward as rapidly as possible. It is expected that the boiler room building will be extended this winter to give room for the boilers required by the six additional 30,000-kw. units which are to be installed.

There are numerous problems in the River Rouge plant which have had their effect on the plant design. One of these is the water problem. The water in the River Rouge or in fact from any of the wells in that location contains about 1000 parts salt in a million.

This naturally meant evaporation for boiler feed. This evaporation problem, however, is different from

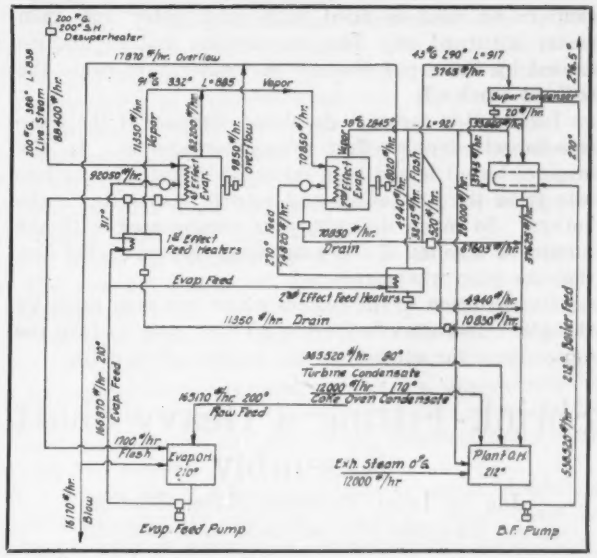


FIG. 9. MAKE-UP OF 20 PER CENT IS SUPPLIED BY A DOUBLE EFFECT EVAPORATOR SYSTEM

that in station requiring only 1 or 2 per cent make-up. Due to the loss of steam in processes, the evaporators are required to supply a 20 per cent make-up. This means a battery of evaporators which at the present time supply about 120,000 lb. of water per hour to the boilers. With the increase in size of the plant it will be necessary to increase the size of the evaporator installation but not in proportion to the capacity required for the first section of the plant since the loss in processes will not be greatly increased. At present the evaporator installaiton is made up of nine double-effect units to which will be added four more units.

Even with distilled water, it is necessary to blow down the boilers due to condenser leakage. The length of time between blowdowns depends entirely on analysis. It is aimed to keep the concentration below 500 parts per million.

One interesting feature of the evaporator operation is in the method of removing scale. Once in 24 hr. each

FIG. 10. DUE TO EXCESSIVE MAKE-UP THE WATER PROBLEM IS UNUSUAL

There are nine double-effect evaporator units and four more sets to be added. The pumps in the foreground have been removed as they were installed in an experimental way to determine whether the condensate from the first effect could be pumped back to the boilers. Trouble was experienced due to the high temperatures. On the right is shown one of the boiler feed pumps.

evaporation unit is filled with cold water and then steam is turned on. The contractions and expansions caused by the rapid changes in temperature cause the scale to crack off.

In Fig. 9 is shown a simplified diagram of the Griscom-Russell double effect evaporator system. In the original layout it had been intended to trap the condensate from the first effect and return it directly to the boilers. So much difficulty was encountered with the pumps on account of the water temperature of 350 deg. that the plan was abandoned.

One addition to the system which has been made by the plant operators is the use of flash pots to take the vapor from the condensate of the first effect coils.

Shrink-Fitting a Heavy Shaft Assembly

Job in India Required Novel Method of Solution Due to Lack of Facilities

WHEN INSTALLING the equipment for the hydroelectric plant of the Andhra Valley Power Supply Co. near Bombay, India, the field engineer for the company furnishing the turbines developed a novel method of assembling shaft, rotor and water wheel runner. For the particular conditions of the job, this method

FIG. 1. SHAFT SUSPENDED FROM CLAMPS AND ABOUT TO BE LOWERED INTO THE STEAM BOX FOR THE FIRST SPIDER
FIG. 2. SHAFT BEING TURNED, SHOWING BLOCK TO KEEP WEIGHT OFF BUCKETS

proved to be much superior to the conventional press-fit.

This plant comprises six 10,000-kv.a. General Electric generators, each driven by a single overhung Pelton impulse turbine. Besides the hydraulic equipment, this engineer and his assistant installed the generators as well. The only labor available was native and was mainly unskilled.

Each shaft assembly comprised four rotor spiders weighing 8 T. apiece, the water wheel runner weighing 12 T., and the shaft itself weighing 9 T.—a total of 53 T. The final assembly weighed 73 T., but the 20 field poles for the rotor, weighing a ton apiece, were

FIG. 3. SHAFT ASSEMBLY BEING LOWERED TO FINAL POSITION

naturally not added until the rest of the assembly was completed. The bore of runner and spider hubs was 0.003 in. smaller than the shaft diameter which was 22 in.

Largely on account of the lack of skilled labor, it was decided to heat spiders and runner by steam and shrink them on, rather than to employ the usual press-fitting methods. Events proved that shrink-fitting would have been advantageous irrespective of the character of the labor supply.

A "steam box" large enough for one of the rotor spiders was constructed, and a spider lowered into it. Steam was then supplied by a 1-in. pipe from a donkey boiler outside the building. Four or five hours of steaming was required, which increased the diameter of the bore from 0.003 in. less than that of the shaft to 0.012 in. more. Further steaming made only a slight additional increase, the time allowed being apparently sufficient to bring the spider to approximately the temperature of the steam.

The first spider to be applied was necessarily the one next to the outboard bearing, so that in up ending the shaft for insertion, it was necessary to grip it by a friction clamp over the journal itself, as there was no collar to keep the clamp from slipping off. The clamp used was composed of two 12 by 12-in. teak timbers fitted to the curvature of the journal, and held together by two pieces of 12-in. I beam 3 ft. long with three 1½-in. bolts at each end. Forged links of 1½-in. steel were looped over the double hook of the crane.

At the conclusion of the required steaming period, the steam was shut off and the box opened. The bore was then wiped out and its diameter checked before inserting the shaft, which went in easily. For the first spider on each shaft a stop was attached to prevent the shaft going too far. The other spiders stopped against the ones already in place. After the first spider had shrunk in place, the lifting clamp was removed and subsequent hoisting was done with slings through the spider.

To guard against looseness in the main key and to insure alinement of the pole slots of the four spiders, a long key with one end tapered was made to fit the slots

exactly, and as each pair of spiders came together it was inserted and left in place until the last spider to be added had cooled and gripped the shaft. The time of cooling was prolonged as much as possible, 12 hr. being usually allowed for it, although the hub commenced to grip the shaft after one hour.

Aside from the cleaning and preparation of hubs and shaft that would be required whatever the method of assembly employed, the actual work for each hub required one man for 8 hr. to tend the boiler, and the crane, and four men for 2 hr. to make the insertion and later to withdraw the assembly and place another spider in the box. The same procedure was followed for the turbine runner except that a slightly larger steam box

FIG. 4. GENERAL VIEW OF ONE OF THE UNITS DURING ERECTION

was required and 7 hr. steaming instead of five. In one instance all five hubs were set on a shaft in as many days.

When the shaft assembly, weighing 53 T., had been completed and was hanging from the crane with the turbine runner down, an overhanging step was provided on one of the pit walls, on which the outer hub of the runner was rested, permitting the entire assembly to be lowered to a horizontal position without placing any weight on the buckets. The assembly was then picked up again and set in the bearings.

Smoke Abatement Campaign Is Renewed

FOLLOWING a study of the problem of smoke abatement made by the Bureau of Mines, Department of the Interior, there is reported renewed activities by civic authorities and organizations in the campaign to eliminate the smoke nuisance.

This campaign was suspended during the World War, when most of the smoke ordinances throughout the country were held in abeyance with the intent of allowing industries to operate unrestrictedly during the time when maximum production was necessary. With the return of normal conditions, many cities have shown a determination to take up this matter seriously and work out a solution. Some 50 or 60 cities in the country have already smoke ordinances, is stated in the report issued by the Department.

Any operation requiring fuel can be conducted without objectionable smoke, and yet use bituminous coal in some form, states Osborn Monnett, consulting engineer of the Bureau of Mines, who conducted the investigation. If smoke abatement were merely an engineering problem, it would present no difficulty. Experience has shown, however, that the problem is not so much an engineering as a psychological one. Until the public is thoroughly roused, demands smoke abatement, and shows continued interest in it, no permanent improvement is possible. Thus the part played by civic organizations and other bodies interested in bettering conditions is of high importance.

From the engineering side, the deposit of soot on the heating surface of boilers and furnaces causes a serious economic loss by interfering with the efficient transmission of heat from the fire to the boiler or heater. In addition, the smoke that escapes into the atmosphere in smoke-ridden communities causes a considerable per capita loss to citizens through the damage to fabrics and merchandise, and also by the necessary extra cleaning and repairs.

Smoke has a serious pathological aspect in addition to its destructive effect on property. Acute lung diseases, such as pneumonia, bronchitis and pleurisy, are affected by these corrosive fumes to a marked degree. Investigators agree there is a direct relation between a heavy smoke-laden atmosphere and the morbidity of the population; moreover, it tends to lower efficiency and increases crime and suicide.

High-pressure plants that produce power for miscellaneous manufacturing establishments are the chief sources of industrial smoke. Most of these plants are hand-fired and consist of comparatively small units, approximately 150 hp. each. Since they make so much of the smoke of the average city, smokers of this class have received most attention and engineering information on such plants is more widely distributed and more thoroughly standardized than other literature dealing with smoke abatement.

Stoker-fired plants have perhaps been most successful in smoke abatement. The boiler units are generally of large size, are equipped with mechanical stokers and have been carefully designed by competent engineers. In addition, these plants are under constant supervision by skilled engineers and firemen are always in attendance.

A person investigating the smoke problem is sometimes surprised to find what a large amount of total fuel used is burned in special furnaces which have no relation to steam making. Most of these furnaces, annealing ovens, for instance, are among the worst smokers with which we have to contend.

Locomotive smoke has seemed most difficult to control, but many cities in the Middle West have attempted to solve this problem with more encouraging results than were at first supposed to be possible. In the past 10 yr., standardized equipment has been designed to reduce the discharge of smoke from locomotives. The equipment includes multi-tip blowers, quick opening blower valves, and induction tubes in the sides of the fire box to supply air necessary for complete combustion. Such equipment is simple, is easily added by ordinary boiler makers and has been discussed in detail in the proceedings of the various railway associations.

Success in smoke abatement depends largely on the administration of existing laws. Perhaps the most important consideration is the type of man for administering a smoke ordinance.

Wood-Shop Power Costs Reduced One-Fifth

PROPER COLLECTION AND USE OF MILL REFUSE AS A FUEL, AND REARRANGEMENT AND SELECTION OF MOTORS WERE PRINCIPAL FACTORS IN LOWERING COSTS. BY MORGAN G. FARRELL

PLANING-MILL waste, in most plants not devoted exclusively to wood working, is generally regarded as a necessary evil to be disposed of, somehow or other, usually by burning it up. Yet its fuel value when properly applied may cut the cost of steam generation 20 per cent and more.

It is easily handled, has a high calorific content, burns freely and completely without smoke, and leaves practically no residue to be wheeled away to the ash-pile.

FIG. 1. THIS CYCLONE AND EXHAUST PIPE MAKE DELIVERY OF SAWDUST AND SHAVINGS FROM THE MILL TO THE POWER PLANT AUTOMATIC AND CONTINUOUS

It is easily fired, requires little attention when properly burned and forms no clinkers. Next to oil it is the ideal fuel to handle, and in point of cost it is second to none.

But it must be burned correctly.

It is not sufficient to clean out the wood shop once a day, truck all the sawdust, shavings, and cuttings to the boiler room and dump them on the firing floor to be shovelled into the furnaces by firemen enthusiastic only to get rid of the litter. Nor is it efficient to feed it through a pipe, clogged with material into the front of an ordinary fire-box. When used in combination with coal, as is usually the case, the result of such firing methods is to smother the fire, choke the draft and reduce the effective combustion of both coal and wood waste.

WOOD REFUSE IS REAL FUEL

The point to be impressed upon the boiler house foreman and his force is that the wood is to be used as fuel to supplement the coal, not that the coal fire is to be a means for consuming the wood.

This sounds elementary enough, but many talks with firemen have revealed the incredible fact that they considered the wood shop waste in the light of so much plant garbage adding an unavoidable burden to their fires. They seemed to consider it just another handicap in their race to keep up steam. And this applies no less to the big lumber and trim-mills than to the class of factories in which the wood-shop is only one unit in the manufacturing process.

It is in the latter, especially, that the greatest economy is to be expected by the proper combustion of the wood shop waste. For the big lumber mills have such a surplus of by-product that they can afford to burn it wastefully; as any one can testify, who has seen the mountains of sawdust piled up and rotting away, around even a small saw mill in the pine woods of the southern belt. The factories in the congested sections of the North, which produce furniture, agricultural or flour-milling machinery, wagons, cabinet work, barrels and boxes, or any of the numerous commodities into which wood enters, have no such surplus. They produce, however, enough to warrant careful thought as to its disposition, and in most cases consideration of its possibilities as a cost reducer. Such possibilities are often ignored, and it is the purpose of this paper to point them out, show what they amount to in dollars and cents and outline the means for utilizing them to reduce power costs.

One typical instance of striking power economy effected by the efficient utilization of wood-shop waste is presented by a large manufacturer of machinery of the general classification of "Agricultural Implements." Their principal product was an assemblage of metal parts, cutters, brushes, etc., encased in a wood frame and housing. They also made presses having heavy timber sills, wood platforms and chutes, and conveyors with wood bolts and casings. Most of the wood used was yellow pine having a high calorific value. The plant included a foundry, machine shop, sheet-metal shop, planing mill and general wood shop.

Due to business expansion, the owners decided to rebuild their largest plant and as most of their customers who were scattered came to the plant to select their equipment, the company decided to make the new factory a model plant with all the latest refinements in machines and methods. Among other features the wood shop came in for consideration.

In the old plant, power was furnished by line-shafting driven by steam engines scattered around the plant, operated from three distinct boiler houses. The old wood shop was not equipped with a suction system for sawdust. All waste was collected once a day and gotten rid of, in the time-honored way. Sometimes it was sold to turpentine makers; again it was burned, or used for filling in outlying hollows on the plot.

SUCTION HOODS COLLECT SAWDUST

When the new plant was being planned, the company officers decided they must have suction hoods on all wood-working machines, without any fixed idea what was to be done with the waste collected. Their engineers, however, visualizing its full possibilities, worked out a plan for utilizing it in the power plant.

Accordingly, the new power house was built with a fire-proof mezzanine floor or bin over the boiler room, to serve as a reservoir for the shavings, sawdust and light cuttings. A complete dust collecting system was installed in the planing mill on the first floor of the factory adjoining the power house, as well as in the

wood-finishing shop on the second floor. Not only was each machine hooded and connected up with the suction system, but sufficient hoppers were provided in the floor under the machines and in the open working space to receive the floor sweepings. Thus, all waste other than large blocks was drawn through the suction fan and discharged through a duct leading to a cyclone separator on the boiler house roof. Thence the wood waste dropped into the shavings bin on the mezzanine directly over the boilers.

As the new plant was to be completely motor-driven with alternating current generated by an engine-generator, and as the load consisted of induction motors, which operate at a low over-all power factor, an ingenious economy in wiring was effected by using a large synchronous motor to operate the suction fan. Tests showed that the plant power factor could thus be increased from 62.5 without the fan in operation to 81.0 with it.

Furnaces for Burning Sawdust

Return tubular type boilers, with dutch ovens were installed. Drop legs fitted with measuring valves led direct from the overhead shavings bin to the center of the top of each dutch oven. In addition there were two larger drop legs leading direct to the firing floor for emergency use.

In the boiler plant was a battery of four 200-hp. boilers, normally operated at about 85 per cent capacity. The fuel consisted of two-thirds semi-bituminous coal and one-third wood waste by weight. A constant thickness of coal fire-bed of about 6½ in. was maintained, and a constant feed of shavings and sawdust amounting to an additional 2½ in. of fire-bed was supplied by regular operation of the valves in the drop legs. After a short period of instruction, the firemen were trained to operate the valves so that just the right amount of fuel was fed at the right intervals to insure complete and continuous combustion. Large blocks and cuttings were wheeled into the boiler house and fired by hand. One fireman and a helper handled the plant as compared with four firemen for the old plant.

Here is the saving in fuel and handling:

(a) Burning coal exclusively:

6000 T. a yr. at $5.50	$33,000.00
Four firemen a yr. at $1500	6,000.00
Total	$39,000.00

(b) Burning two-thirds coal and one-third wood waste by weight:

5000 T. coal a yr. at $5.50	$27,500.00
2500 T. waste a yr	
One fireman, one helper a yr	3,300.00
Total	$30,800.00
Annual saving by burning waste	$ 8,200.00

That is: The annual saving in the actual operation of the boiler house amounted to slightly over 20 per cent.

Figure 1 shows the shavings exhaust pipe leading from the work shop in the first floor of the factory building at the right to the cyclone separator on the roof of the power house over the storage bin. The longest run of duct was 410 ft. from the most remote machine to the separator. Yet there was never any difficulty experienced either through insufficient suction or clogged pipes.

Features Affecting Power Economy

Fuel and labor saving, however, are not the only factors to be considered by the mill owner who contemplates modernizing his power system. There are related economies which are of equal importance. The power question should be considered as a whole, together with its effect on plant insurance and efficiency.

For instance: a furniture plant near a large city in Pennsylvania included in its building group, three separate mills and a central power plant. The buildings were old and dark. A Corliss engine furnished power through a rope drive to line-shafting. There were a few suction hoods on some of the machines but they were so badly placed and the piping so poorly designed, that the exhaust system was ineffectual at its best. Usually it was wholly or partly out of commission. The machines were covered with wood waste, and the floor around them was ankle deep in sawdust and shavings.

As the ventilation was bad, the air was full of fine dust, particularly in the wood finishing room. As a result, the labor turn-over was heaviest at the point where there was most need for high-class experienced operators. Minor fires were of too frequent occurrence. Finally a fire caused by static discharges from the belting, wiped out one of the mills and for a time, threatened the whole plant.

Naturally the insurance rate was the maximum applicable in the locality, about $2.75. While the burned mill was being replaced, the management decided to get rid of the mechanical drive altogether. A careful survey showed that the total annual power cost, averaged over 7 yr., had been over $67,000.

This cost, the owners had assumed, must be fairly low, for they burned all the waste (by hand) and used the engine exhaust for the dry kilns. The report of their engineers disillusioned them. They were shown that the total connected load in a motor driven plant would be 1250 motor horsepower. With a load factor of 40 per cent the power demand would be about 500 hp., that is about 375 kw. At 3000 operating hours a year the total consumption of electrical energy would be 11,250,000 kw.-hr. annually.

Hence their power had been costing them about 6c a kw.-hr., if the engine exhaust had supplied all the steam necessary for heating, steaming and drying. The public service company had repeatedly offered to supply current for an average of 3c a kw.-hr.—half the cost mentioned.

Of course the engine exhaust had not supplied all the steam necessary for heating, steaming and drying—nor anything like it. Live steam had been used for "make-up" in the kilns, for steaming wood, for hydrosteam lifts and to help heat the mill in winter. Besides, the friction load of the transmission was found to be 40 per cent of the engine load.

Changes contemplated were carried out in full. They included: direct connected motors for planers, saws and all large machines, group drive for the smaller ones, the purchase of electric power, the installation of complete suction systems in each mill, and the alteration of the necessary number of boilers for the proper combustion of waste.

XUM

Power costs for the first year of operation were:

11,880,000 kw.-hr. at $0.03	$35,640.00
2640 T. wood waste	
1495 T. coal at $6.15	9,195.00
One fireman, one laborer	3,600.00
Total	$48,435.00

which represents a saving of nearly $19,000 a year.

In addition, the fire hazard of the mill was reduced by these and other changes so that the new rate effected an annual saving in insurance of about $3000. Moreover, the improved working conditions have materially diminished the labor turn-over.

These examples of the potential value of wood shop waste as fuel have been cited at length since they illustrate perfectly the conditions which are known to prevail in a great many wood-working plants. Moreover, they graphically demonstrate the meaning in dollars of properly collecting and burning the waste.

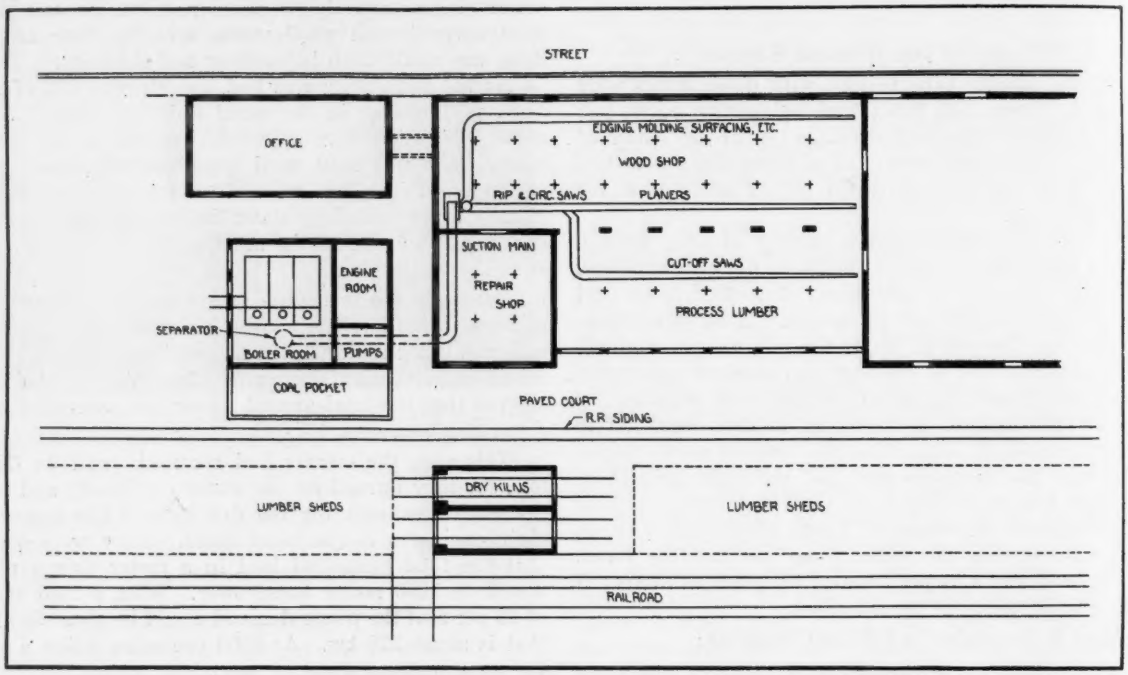


FIG. 2. DUCT SYSTEM FOR COLLECTING AND DELIVERING MILL REFUSE

Difficulties in Burning Wood Refuse

It may be useful to comment on some of the details of the equipment best suited to the purpose. First in importance is the type of furnace. It has been already stated that wood waste cannot be burned successfully in an ordinary fire box. The fuel is so light that much of it will be carried back under the boiler shell or tubes and remain unconsumed. Moreover, it burns with so much heat that it will actually damage the boiler unless it is completely consumed within the furnace. Then also it must be made to store up heat in the walls, so that only the hot gases will flow back over the bridge giving up their calorific value as they pass on under the shell and through or around the tubes. If the combustion is continued back of the bridge, this heat will not be fully extracted by the boiler parts, resulting in a high temperature of the flue gases with a consequent loss.

Hence the dutch oven type of furnace built out in front of the boiler is best adapted for burning wood waste.

Features of Furnace Design

It should be built of common brick lined with not less than 8 or 9 in. of high-grade fire brick laid in the best fire-clay or one of the patented fire-cements. It is poor economy to reduce the thickness of the fire brick walls; in fact, best results can be obtained by leaving a 1-in. air-chamber between the fire brick and common brick. It is still less economical to use low-grade fire brick with a low fusing point, for this will result in rapid deterioration and frequent shut-downs for relining.

In the first of the plants previously mentioned, it was not uncommon, under the old method of operation, to reline the furnaces every three months. If good brick had been used, an annual relining would have been ample. Another important factor in assuring complete combustion is the height from the grate bars to the arch. It is hardly possible to make this height too great, but usually it is from 25 to 50 per cent higher than for coal burning. This has the incidental advantage of prolonging the life of the arch brick—an important consideration where expensive, shaped brick are used.

As far as the combustion chamber back of the bridge-wall is concerned, it will usually be of sufficient size in any return tubular boiler which has been altered by the removal of the existing fire-box and the addition of a dutch oven. The grate area of the oven should be increased above the requirements for coal burning. The amount of increase can usually best be left to the manufacturer of the boiler, as the draft requirements vary with the kind of waste, the type of grate bars, the coal

used as auxiliary fuel and the internal dimensions and baffling of the boiler.

The sawdust and shavings pipe may enter the dutch oven either through the top or the front. There is a difference of opinion on this point; but the writer's observation favors the top connection, with the opening a little forward of the center of the grate. This assures a better distribution of the fuel and keeps the boiler front clear of obstructions. There is little danger of back-firing into the feed pipe; none at all where a measuring valve is used. The latter consists simply of two horizontal damper slides about 3 ft. apart on return tubular boilers, connected by a linkage which closes one slide when the other is opened. Its object is to feed a charge of fuel which will not be large enough to smother the fire.

As previously indicated, the coal fire bed may be maintained at a lesser thickness when wood is being burned than when coal is used exclusively. The exact thickness to produce best results will have to be determined by experiment, as it depends on the class of coal and the relative proportion of waste. The thicker the bed of waste the greater must be the draft, for a sawdust bed particularly, since it packs much more tightly than other fuels.

Rules Observed in Planning Duct System

For a large mill, the duct system requires special study for each case. A few general rules, however, may be given.

For example, the flow should be generally downward. The mains for upper floors should be under the floors as far as possible. Very small pipes (except for sanders, etc.), and sharp bends, pocket and the like should be avoided. It is not necessary to increase the diameter of the main ducts for each incoming branch, nor in proportion to the areas of the branches. The best results are secured by keeping the diameter of the main down. In the illustration, Fig. 2, the main duct leading from the factory to the separator is 32 in. in diameter, about 800 sq. in. Yet it receives the discharge of over sixty 6-in. branches and many smaller ones.

For use as an exhauster in the wood shop the type of fan best adapted is of the plate or conoidal type, of rugged construction with ample bearing surface. Practically all the large manufacturers include, in their line, fans of the proper type. As the fan is the life of the entire exhaust system, the best is the cheapest.

Electric Hoist Rake Clears Forebay of Trash

FEW hydroelectric plants have to fight against as much trash in the forebay as the Morgan Falls station of the Georgia Railway & Power Co. on the Chattahoochee River. The surface of the river is covered with trash and in addition there is a lot of trash that is submerged. The result is that the booms do little except divert the upper layer. Included in this debris are water-logged stumps, branches of trees, trunks and even old scows. The spring freshets wash down great quantities of this material.

After several years of experience in handling such trash by various methods, W. C. Sullivan, foreman of the Morgan Falls station, devised an electric hoist rake that he constructed out of surplus material found around the plant. This rake had proved highly satisfactory in handling the accumulated trash. It is rigid and heavy and doesn't get out of order. Furthermore, it handles the material rapidly.

It consists of a structural-steel rake with tool-steel teeth and a 1⅜-in. steel handle that slides through a short section of pipe attached to the motor-driven chain-hoist carriage. The hoist carriage runs on a plow-steel cable stretched between supports so that it runs over the top of the forebay racks.

About 24 ft. upstream from the racks and just above the water level is stretched a ½-in. guy wire carrying

POWER OPERATED RAKE CLEANING TRASH RACKS

a dolly to which a ½-in. block and tackle is fastened for pulling the rake away from the racks while lowering it to take a load.

In making the rake, a 9-ft. "L" that measures 7/16 by 3 by 6 in. is used. To this are fastened U-shaped teeth 27 in. long. Strips welded between the tips of two teeth at each end of the rake keep the teeth from projecting through the rack. The handle of the rake is 35 ft. long. It is flattened at the lower end and bolted to a piece of strap iron, which in turn is bolted to the rake cross-member. A ring is also fastened to this strap for attaching the chain from the motor-driven hoist and the block and tackle for pulling away the rake from the racks in lowering. Chains containing turn-buckles at the upper ends tie the outer ends of the rake and the intermediate parts to the handle. The one-ton electric chain hoist is equipped with a 35-ft. lift chain. In clearing away the trash that is raked onto the platform at the top of the racks, it has to be loaded onto a flat boat with coke forks.

Governors for Hydraulic Turbines

RECENT IMPROVEMENTS IN GOVERNOR DESIGN HAVE CONSISTED IN SIMPLIFICATION OF DETAILS. BY W. M. WHITE*

HYDRAULIC TURBINE governors are designed to regulate the speed of a unit by increasing or decreasing the amount of water supplied to the turbine to maintain a balance between water input and power output when a change in power output causes a fluctuation in speed. Turbine governors perform their functions in a more or less satisfactory manner, and thereby derive reputations as good, fair, or poor governors. Many governors, however, which are capable of performing their duty of speed regulation in an excellent manner and which thereby fall into the first class of good governors, have been consigned to the last class, as poor governors, because the accessory equipment or other minor parts are constantly causing so much trouble and requiring so much attention that their defects entirely overbalance the good points.

Ten years ago, governors had reached a stage where as a means of regulating speed they were quite satisfactory, and the fact that but few vital improvements have been made in their main elements proves that fundamentally they were correct. Further, the increase in the capacity of turbine units from a maximum of 25,000 hp. in 1913 to 70,000 hp. in 1923 has not required any fundamental changes, since the problems to be met in regulating a super-unit of 50,000 or 70,000 hp. are not fundamentally different from those encountered in regulating a 500-hp. unit, the principal difference being only in the masses to be moved. In spite of this fact, the large capacity units have been responsible for the changes that have been made recently in governors. These changes have been principally in the nature of simplification of accessory equipment and minor parts so troublesome on many governors, because the cost of one hour shut-down on a 40,000-hp. turbine is approximately 80 times as much as on a 500-hp. machine, although a broken governor belt or oil pipe on either unit may be replaced at about the same cost. In other words, it may be said that recent improvements and changes in governors have been intended to simplify the accessory equipment and increase the reliability, to prevent as far as possible unnecessary interruption on large capacity units.

For the purpose of this discussion, we may consider a governor to consist of five main parts:

1. The oil or fluid supply under pressure.
2. The flyballs, or other means of registering a speed change.
3. The distributing valve.
4. The regulating cylinders or servo-motors.
5. The restoring or relay mechanism.

Fundamentally the action of a governor is that a change in speed causes a corresponding change in the position of the rotating flyballs, which in turn moves the distributing valve so that oil under pressure is let into the regulating cylinders, causing them to move the gate mechanism of the turbine. This movement of the gates is transmitted back to the distributing valve through the restoring mechanism, bringing the distributor valve back to its original position after the gates have been moved.

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Efforts of the engineers of the company with which the writer is connected have been directed toward arranging these elements in such a manner that the simplest, and most dependable possible combination will be obtained. Figure 1-C shows an arrangement of governor equipment which accomplishes these results. This is what is known as the Integral Governor with direct connected flyballs. Figure 1-D shows a typical construction of the direct connected governor flyballs patented by the writer. It is mounted directly on the main shaft of vertical units and the flyball motion is transmitted to the distributing valve through the rod (70) shown at the left.

In the older type governors, the flyballs were mounted in a housing located on the generator floor, either driven through bevel gears and a horizontal jack shaft or through a horizontal belt on edge, running from a flanged pulley clamped around the main shaft to a pulley on the flyball shaft. Delicate governors are affected by the lacing and joints in ordinary belting and therefore require the use of special belts and joints. Small governor shafts at high speeds require frequent lubrication and attention. High speed flyballs located on the generator floor require lubrication, and unless completely enclosed in oil tight housings the result is a ring of oil thrown onto the floor.

Dampness and moisture cause deterioration and stretching of ordinary belting. Dampness unavoidably exists in the lower part of the water power plant, so belts must be frequently taken up or else provided with an adjustable idler pulley for taking up the slack. Bevel gears on jack shaft driven governors are usually made, one of fiber and one of metal. Moisture causes warping of fiber gears which results in noisy running. Also a jack shaft must have at least two bearings which must be lubricated and watched. Direct connected flyballs mounted on the main shaft are freed from all these troubles, and have been used for speeds from 80 to 900 r. p. m. and on units from 300 to 40,000 hp. rated capacity, and are now being constructed for the 70,000-hp. unit at Niagara Falls.

The governor stand, containing the distributing valve, dashpot, speed adjustments and gate opening indicator in many large plants, is located at a considerable distance from the turbine which it regulates. Where the regulating cylinders are located directly on the cover plate of the turbine and connect directly to the shifting ring, that is, in the case of units of large size where it is not desirable to transmit the governor forces through a regulating shaft, governors of the integral type, shown in Figs. 1-A, 1-B, and 1-C, have been mounted directly on one of the regulating cylinders. All governors require a certain change in the speed of the unit before the distributing valve is moved. The period of delay between the instant of load change and governor action, known as lag, greatly affects the quality of speed regulation.

Mounting the governor stand with distributing valve directly on top of one of the regulating cylinders reduces the length of connecting pipe to a negligible amount. The connection can be larger, many elbows

FIG. 1. SIMPLIFICATION OF DETAILS TO INSURE GREATER RELIABILITY HAS MARKED THE RECENT DEVELOPMENT OF THE HYDRAULIC TURBINE GOVERNOR

A. View of turbine pit showing compact arrangement of integral governor.

B. Governor stand mounted on regulating cylinder shortens and simplifies all connections.

C. General view showing relation of integral governor to the unit.

D. Direct connected governor flyballs.

E. Semi-self-contained governor equipped with motor operated load limiting device.

F. Actuator type governor stand showing master valve located below dashpot.

and bends are eliminated, and danger of leaks is reduced in proportion to the length of pipe and the number of joints omitted. Furthermore, the relay or restoring mechanism is simplified, only one short rod being required, as shown in Fig. 1-B, as compared with the long length of rod, a number of bell crank levers and supporting bearings, required to transmit the motion from the turbine to a distant governor stand. The lost motion occurring in many joints and bearings, especially after years in operation where lubrication is neglected, seriously affects the regulation. The integral construction concentrates all the hand controls, starting valves and indicators on the turbine, where the man at the governor can observe the shaft as it starts to rotate and come up to speed.

This integral arrangement, when used with the direct connected flyballs, does away with a multitude of small parts always liable to give away at a critical time. Super-units represent a large investment in capital, and a loss of their earning power, for even a few hours only, mounts up to hundreds of dollars, consequently any modifications of governor equipment designed to simplify connections and reduce the number of small parts are highly desirable.

As another means of eliminating the use of belts, jack shafts, etc., motor driven flyballs have been tried out. These, however, have the disadvantage that the unit cannot be brought up to speed with them, since usually the generator is not excited until it has reached normal speed. A further disadvantage with the motor driven flyballs is that in case of a short or burnout of the generator the current supply fails, which is the time at which the governor is most badly needed. Some of these disadvantages may be overcome by mounting a separate generator on the turbine shaft, for driving the flyball motor only, but this runs into additional complications.

Small units were usually started up, synchronized, and their speed adjusted by an attendant at the governor. Present day units, however, of the larger size, practically require that they be under the immediate control of the operator at the switchboard. The use of the synchronizing motor for adjusting the speed after the unit had been started up by hand, has not come into common use. Some governors are now so designed that the unit may be started up from a dead stop by the switchboard attendant by means of the synchronizing motor, and after the unit has been disconnected from the line the gates may be completely closed from the switchboard.

Use of the load limiting device, an arrangement by means of which the maximum load on the turbine may be limited to any fractional part of the turbine capacity, has proved a desirable addition to governor equipment. This enables plants to be run on blocked load, using just the flow of the river, and leaving the load fluctuations to be taken care of by another station. This is especially helpful on large systems, where a load dispatcher instructs each plant superintendent how much load to carry. The load limit may be set to this amount and the turbine will maintain that load indefinitely; it cannot open up even in case of a short circuit, but the governor is always ready to shut down in case load is lost, just as though the load limit were not in use.

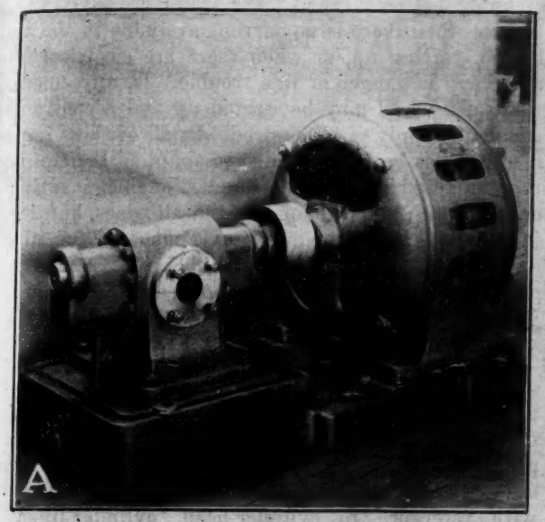
An addition which greatly increases the value of this device is Mr. Pfau's motor operated load limiting device shown in Fig. 1-E. The right-hand motor on top of the governor operates the synchronizing device, while the left-hand one adjusts the load limit through a belt and ratchet. This enables the switchboard operator to adjust his blocked load and watch his wattmeters at the same time, doing away with the old system of signalling to the second operator. The governor shown on Fig. 1-B, in addition to its motor operated load limiting equipment, is provided with electrical contacts which light position indicating lights on the switchboard, one set showing the per cent gate opening, and another showing the load limit setting in per cent of gate opening. The motor operated load limit provides added safety since it enables the switchboard operator to close the turbine gates from the switchboard, independently of the synchronizing motor equipment.

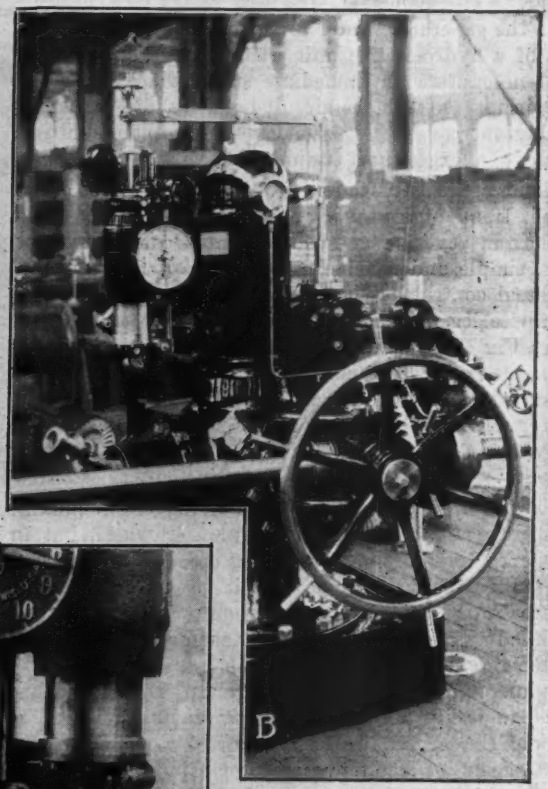
As the load limiting device prevents the governor from opening the turbine gates beyond a fixed amount, irrespective of the speed of the unit, such a device controlled from the switchboard permits of paralleling the unit from that point instead of with the synchronizing device of the relay of the governor, and if overtraveling of the turbine gates is eliminated the paralleling can be done more readily. A unit can thus be put in service quicker than is the case with a remote controlled synchronizer, acting on the governor relay.

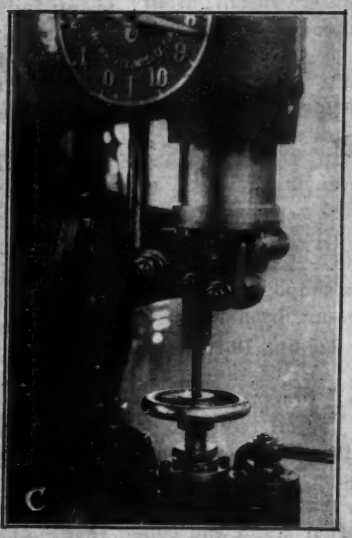
Since the overtraveling of the gates is eliminated with the load limiting device the governor can have no tendency to hunt, whereas hunting is often experienced when paralleling units which lack adequate flywheel effect. Cases are on record where the lack of flywheel effect rendered it impossible to parallel the unit with the ordinary synchronizer of the governor, whereas the paralleling of such a unit can still be accomplished with ease with the remote-controlled load limiting device.

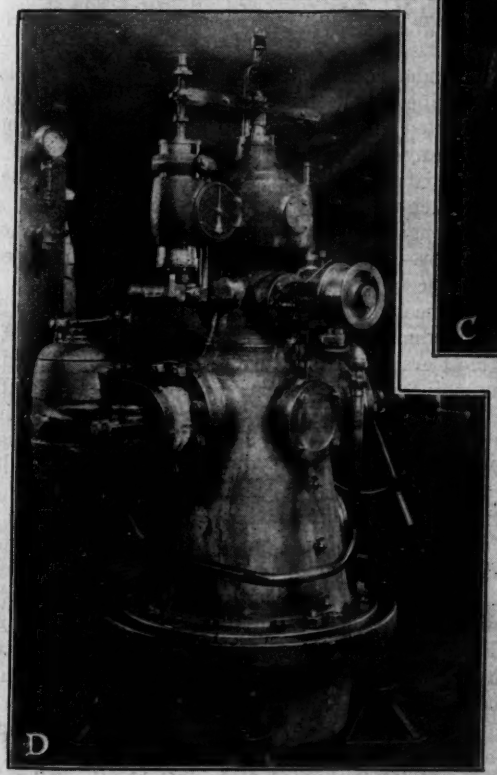
Where a hydroelectric unit is tied in to a large power system it is relatively easy for the governor correctly to participate in the control because the percentage load change of the system is smaller and the rotating masses engaged in the system are so liberal that the governor will not have to act quickly. When the unit is to be paralleled, however, the control must depend exclusively on the rotating masses of the unit itself, and therefore, if the flywheel effect is small, hunting is inevitable, and since such a unit can still be satisfactorily paralleled with a remote controlled load limiting device, it follows that such units can be provided with a small flywheel effect and still be handled readily.

In several plants, serious damage has been done to electrical equipment due to prolonged short circuit and burn-outs, the turbine running wide open and the operator either too excited or for some reason unable to shut down the turbine. The emergency shut-down device shown mounted on the side of the governor in Fig. 1-B has been designed to simplify and speed up the operation of shutting down, the energizing of a solenoid being all that is required to effect complete closure of the gates of the turbine, the action being almost instantaneous. This feature might be classed among the list of equipment for automatic station operation, since it forms the heart of the protective equipment there, but even in non-automatic stations its use is of great assistance. The operator by touching one button can shut









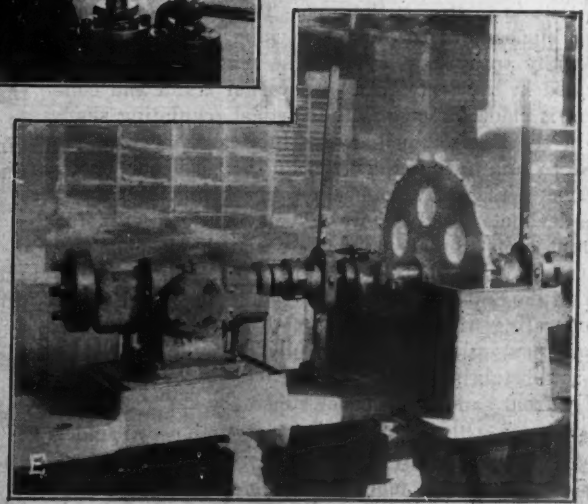


FIG. 2. MANY GOOD GOVERNORS HAVE BEEN A CONTINUAL SOURCE OF TROUBLE BECAUSE OF FREQUENT FAILURE OF SOME SMALL PART OF THEIR ACCESSORY EQUIPMENT

A. Direct connected gear type oil pump.
B. Semi-self-contained governor showing hand controlled gears mounted on the outside.
C. Master valve for shifting to manual control.
D. Direct connected governor flyballs.
E. Water wheel and motor driven pump

the turbine off completely or it may be connected up to bearing thermometers, overload relays, temperature coil in the generator, water level floats, or to any of the parts of a hydroelectric unit where unusual conditions would necessitate an immediate shutdown. Connected to act in unison with the circuit breakers, disconnecting switches and air brakes, it makes the complete shutting down of the largest unit simple, positive and rapid.

Hand control instead of governor control of large units is frequently essential and in order that the transition from governor control to manual control may be quick, simple and reliable, a new type of master valve and hand control has been devised. Figure 1-F shows the device located below the relay dashpot of the governor, Fig. 2-C showing an enlarged view of it. A quarter turn of the handle at the right connects the oil pressure to either the governor control or manual control regulating valve. By turning the small handwheel and watching the gate position indicator just above it, the position of the gates may be adjusted as desired.

Large units generally have motor driven oil pumps, frequently augmented by a small water wheel, but in emergency, and frequently during erection, it is necessary to furnish the required oil pressure by hand. Figure 1-A shows the hand oil pump mounted on the left hand cylinder, this forming a compact arrangement for the integral governor arrangement. Instead of the old plunger pump, a small gear pump is used and one man can easily spin the hand wheel for moving the gates of the largest turbine. Figure 1-F shows another arrangement of hand operated gear pump located on the governor stand of the governor. All connections being contained within the housing, a simple and reliable method results for obtaining oil pressure by hand.

Figure 2-D shows a governor for 325-hp., 10-ft. head, vertical shaft, open flume turbine. All of the equipment, with the exception of a small pressure tank, is combined in this governor stand. The oil reservoir or sump tank is located in the base. The flyballs are completely enclosed in the upper housing where they are continually sprayed with oil. The regulating cylinder is located in the center of the governor stand and connection is made directly to the vertical regulating shaft held in the bronze lined grease lubricated bearing attached to and forming a part of the governor itself. This makes the relay connection simply one short rod to the dashpot directly above. The synchronizing motor is mounted on a bracket directly above the dashpot and the load limiting device operates with the regulating valve on the opposite side of the stand. The hand wheel for operating the gates by hand is located on the threaded extension of the regulating cylinder piston rod, a substantial lock being provided for changing readily from hand to governor control.

In the majority of the larger installations oil under pressure is pumped by motor driven oil pumps, sometimes one pump and motor for each unit, sometimes a central oiling system where oil for several units is pumped by one or two large pumps. Figure 2-A shows a direct connected motor driven gear type oil pump, both pump and motor mounted on a common cast iron base, such as is frequently used for a unit oiling system. Figure 2-E shows a pumping unit for a large central oiling system. There are two pumps, each of which is direct connected to its motor, and so arranged that either or both may be driven by a small water wheel mounted between them. The water wheel is valuable for use when there is no current available in the station before starting up, or when there are electrical storms and there is danger of line trouble. In any emergency the water wheel may be started up and a constant and adequate supply of oil assured. In all of these improvements it has been the aim so to simplify the equipment that its reliability will be unquestionable, insuring not only proper regulation of speed at all times, but decreasing to a negligible amount any chance of forced shutdown because of failure or trouble with a minor part of the auxiliary equipment.

Progress in Oil Engines

DURING the past year the manufacturers of oil engines have continued to make minor changes to existing designs in order to simplify the operation of their engines and to render them more reliable. Extensive studies have been made by all makers of Diesel engines with reference to cylinder-head, cylinder-liner, and piston failures. Facts regarding failures of past years have resulted in improved regulation of cooling, a marked tendency toward simplification of cylinder-head structure, and extensive research in the field of better materials of construction. Closer co-operation between the engine builders and engine users has resulted in redesign and improvements in engine parts which have been shown to require close attention and periodic renewals.

The tendency toward the use of lower grade fuels for Diesel engines has been marked and the fuel oil situation in the United States, no doubt, well warrants this movement. Many builders have successfully improved fuel pumps and fuel valve atomizers to properly handle the cheaper fuel oils. Continued experimentation with solid injection engines using cheap fuel with fuel pumps operating at pressures of 3000 to 4000 lb. has resulted in several successful engines of this type.

Main bearings and crank-shaft failures have been greatly reduced and there seems to be little doubt but that most crank-shaft failures of the past have been due to lax maintenance methods. Crank-shafts for small engines are still made from solid forgings while the introduction of the built up, 3 or 4 piece shafts for engines above 500 hp. has become popular among engine builders.

ONE OF THE most important problems connected with the development of the mineral resources of interior Alaska has been that of obtaining a suitable and cheap fuel for mining operations. Hence the Alaska Experiment Station of the Bureau of Mines, Department of the Interior, has, since its installation in 1916, been virtually interested in encouraging the use of coal from the Nenana field. During the past year a 4-mi. spur was completed by the Alaska Railroad from Healy on the main line to the extensive coal deposits at Suntrana, thus making this easily mined fuel available throughout the whole interior. The Bureau of Mines station has kept in close touch with the coal-mining developments at this point and has offered every possible encouragement to the economical mining and marketing of this fuel. Many conferences have been held with lode and placer mine operators urging the advantage of this fuel and advising as to equipment best adapted for burning it.

Diesel Engine Shows Low Fuel Consumption

LITTLE VARIATION IN CONSUMPTION BETWEEN HALF LOAD AND FULL LOAD SHOWN IN ACCEPTANCE TEST AT SOUTH RIVER, NEW JERSEY, PLANT. BY RAY C. BURRUS

IN MARCH of this year, the Borough of South River, N. J., decided to increase the size of its power plant by the addition of a second Diesel engine unit. The first unit was placed in operation on Sept. 28, 1922; a 520-b.hp. Fulton, direct connected to a 416-kv.a., 0.6 power factor General Electric generator, equivalent to 335 kw. at 0.8 power factor. The first engine contracted for by the Borough, was purchased to replace three producer gas engines, the power costs of which had been greatly increased in recent years due to advance in the price of coal.

Shortly after the first Diesel began operation, it was apparent that the old producer gas plant could not be relegated to a standby status on account of the continued increase in the power demands of the South River industries. The 520-b.hp. unit could easily handle the night load and a large portion of the day load, but at no time were conditions such that the fires could be drawn under the gas producers. At peak loads, the 335-kw. Diesel was called upon to deliver power at the rate of 400 to 410 kw.

Diesel engines are usually sold under a guarantee that they will deliver 10 per cent overload for a given number of hours, usually less than four. It is generally recognized that a Diesel should not be operated continuously above its rating; however, the South River engine, for a period of about 3 mo. during the first part of the present year, ran at overloads from 16 to 22 per cent, 2 to 6 hr. a day. These overloads occurred on week days, when motors running in South River's industrial plants constituted the major portion of the power demand.

After several months successful operation of the first unit, the municipal authorities purchased a second engine, early in the year. This unit is a 700-b.hp. Fulton, direct connected to a 475-kw., 0.8 power factor General Electric generator. Like the first installation, the electrical characteristics are 2-phase, 60-cycle, 2300-v. Since the new engine is of the same design as the first, the parts are interchangeable. The extension shafts of the engine carry direct connected exciters, with leads to a single exciter panel of the switchboard. In an emergency the exciter of one unit may furnish excitation to the other. In addition to this safeguard, a motor-generator set is available, and has capacity to excite both generators.

Operation of the new unit was begun during the week of Sept. 9, and acceptance tests were made on Sept. 18. E. B. VanNess, superintendent of the Board of Public Works, directed these tests. The early morning hours were selected for the full load test, as at this time the power demands were such as to assure loading the engine to its rating. The accompanying tabulation summarizes the results. The computed results of the table are based upon the generator guarantees made by the General Electric Company, as follows:

K.W.	Power factor	Full load	¾ load	½ load
594	Unity	94.3	93.7	92.2
475	.8	92.5	91.8	90.0

As the load variations and test results are better noted graphically, the curves of Fig. 2 have been made up from the readings taken in the test. The smoothness of operation was interrupted but twice during the 2-hr. period recorded, when the plant load mounted far above the normal rating of the generator. In both instances, the voltage dropped slightly, due to slowing up the engine. In each case, the potential was brought back to normal by cutting out a small motor driven water pump, a part of the Boroughs' waterworks equipment. The r.p.m. was not accurately noted during the first voltage drop, but during the second drop the r.p.m. did not fall more than five revolutions from 164, the rated speed.

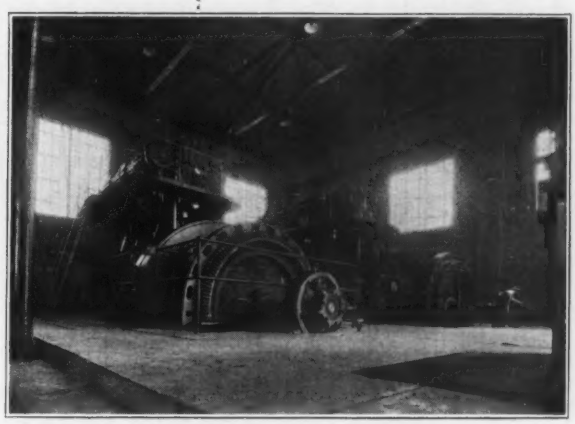


FIG. 1. SOUTH RIVER STATION IS RATED AT 1220 B.HP.

It was desired to test the engine at reduced loads. In order to accomplish this, it was necessary to operate the 520 b.hp. unit to supply the surplus demand for power over the reduced load on the 700 b.hp. Diesel engine. For the purpose of direct comparison with the fuel oil consumption guarantee, an attempt was made to run a half load test. This was somewhat difficult, as the total plant load minus half load for the new engine, i.e., 237.5 kw., gave the smaller engine less than half load. This load condition resulted in the tendency on the part of both units to "steal" the load away from the other, making it practically impossible to hold the

SUMMARY OF ACCEPTANCE TEST RESULTS

Load, per cent	62.2	101.0
Fuel oil consumed, gal	13.0	85.0
Weight per gal., 72 deg. F	7.027	7.027
Weight of fuel oil consumed, ½ hr.	91.35	.....
Weight of fuel oil consumed, 2 hr.	.....	597.35
Total kw.-hr. output, ½ hr.	140.0	.....
Average power factor	.745	.78
Generator efficiency	.8845	.923
Total b.hp. hr. output, ½ hr.	212.2	.....
Total b.hp. hr. output, 2 hr.	.....	1394.7
Fuel oil consumed, lb. per kw.-hr.	.652	.622
Fuel oil consumed, lb. per b.hp.-hr.	.4305	.428
Kw.-hr. generated per gal.	10.77	11.3
B.hp.-hr. generated per gal.	16.32	16.4

test load constant. Therefore, for checking the guarantee an extract from the reduced load readings was selected; this section of readings covering a 30-min. period when the engine load averaged nearly 60 per cent of the engine lubricating oil, and to the switchboard a 10-point Tirrill regulator has been added. One year's operation has greatly reduced power costs, and as the new 700 b.hp. unit gives sufficient Diesel capacity to cut out

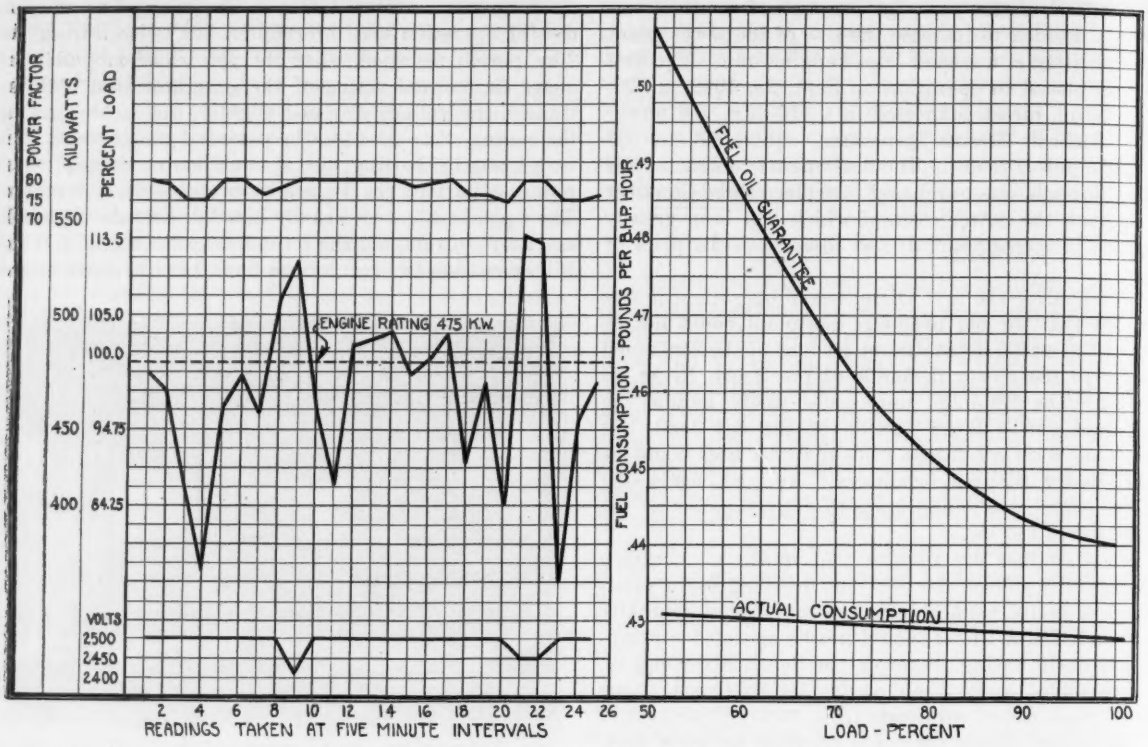


FIG. 2. SOME GRAPHIC RESULTS OF THE ACCEPTANCE TEST

A. During the 2-hr. run, there were two peak load conditions. The voltage fell off slightly although the engine speed dropped only about 5 r.p.m. B. A comparison of the actual consumption curve with the guarantee shows quite a marked reduction due largely to some improvement which had been made in the fuel injection valves.

rated capacity. During the reduced load tests, as in the case of the rated load tests, the exhaust showed perfectly clear.

During the test period referred to, with an average power factor of 0.745, the unit generated 140 kw.-hr. and consumed 13 gal. of oil.

Figure 2A compares the actual fuel oil consumption with the guarantee. While the fuel oil consumption has only been determined for averages of 101 per cent and 59 per cent load factors, it is obvious that the actual fuel consumption curve between these points must be very nearly a straight line as shown.

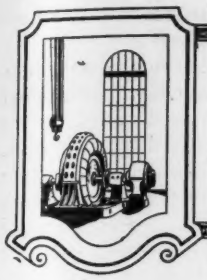
Some months ago, Professor W. B. Gregory of Tulane University, New Orleans, made the acceptance tests on two Fulton engines in the municipal plant of Crowley, La. These tests, made on a 380 b.hp. engine, resulted in a consumption line somewhat steeper than that of the South River Diesel, and the economy was not quite as high. In the past few months some improvements have been made in engines of this type particularly with regard to the oil injection valve. The performance of the South River engine indicates that these improvements have been effective.

With the completion of the installation of the second unit, South River has a modern plant throughout. No detail has been omitted in making the plant complete. A De Laval oil separator has been installed to clean the entirely the producer gas engines, the next year will show a more substantial decrease in the production cost per kw.-hr.

Reagents for Feed Water

AMOUNTS OF reagents required for the treating of 1000 gal. of boiler feed water containing one grain per gallon of the different scale-forming substances mentioned are as follows:

Substance in Water 1 Gr. per Gal.	Treating Substance Required Per 1000 Gal. Water	Resulting Compound
Calcium Sulphate	0.111 Lb. Soda Ash.	Calcium Carbonate
Calcium Bicarbonate	0.117 Lb. 90 per cent Hydrated Lime	Calcium Carbonate
Calcium Chloride	0.137 Lb. Soda Ash.	Calcium Carbonate
Magnesium Sulphate	0.14 Lb. Soda Ash and 0.098 Lb. 90 per cent Hydrated Lime	Magnesium Hydrate
Magnesium Bicarbonate	0.28 Lb. 90 per cent Hydrated Lime	Magnesium Hydrate
Magnesium Chloride	0.18 Lb. Soda Ash and 0.123 Lb. 90 per cent Hydrated Lime	Magnesium Hydrate
Carbon Dioxide (Free)	0.24 Lb. 90 per cent Hydrated Lime	For absorption



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Principles of Alternating Current Control

PART II. WOUND ROTOR INDUCTION MOTORS, SYNCHRONOUS MOTORS. BY GORDON FOX

WOUND ROTOR induction motors have characteristics which are strongly affected by the resistance of the secondary circuit. This makes it possible to secure excellent starting performance from motors constructed in such a way that their secondary circuit resistance may be varied during the starting period. The wound rotor induction motor has its rotor windings brought out to slip rings so that any desired value of external resistance may be connected between these rings. The external resistance may be varied at will. By this means it is possible to limit both starting current and torque to desired values. After the motor has started the resistance may be adjusted to secure the desired running conditions. The conditions which govern the starting performance of a wound rotor type of induction motor may be most readily observed by inspection of the characteristic curves of a motor of this type. Figure 1 gives a typical set of curves showing the relations between torque, speed and primary current with various values of secondary resistance.

In starting a motor, we deal first with the conditions at zero speed. It will be noted that curve A, showing a condition of low secondary resistance, indicates a standstill torque somewhat less than full load motor torque and a corresponding primary current (with full primary voltage) of about four times full load value. As soon as some speed is attained, the torque increases and the current rapidly decreases. This condition is comparable to the starting condition for a squirrel cage type of motor. Curve B shows that an increase in secondary resistance produces greater torque at standstill with lesser primary current. Curves C and D show further improvement until, with resistance as of curve D, we secure maximum or pull out torque of the motor with a current about three times full load value. If we increase the secondary resistance still further as shown by curve E, the torque at standstill decreases, the maximum torque now occurring at negative speed corresponding to a "plugging" condition. The primary current at standstill has also decreased. Curve F shows that, by insertion of sufficient secondary resistance, it is possible to secure full load torque at standstill with approximately full load primary current input.

All of the above curves show conditions existing with full voltage impressed upon the primary winding of the motor but with the secondary resistance varied. Since it is possible to control the starting performance of motors of this type so excellently by adjustment of the secondary resistance there is no need for the reduction of the impressed primary voltage during the starting period. The primary winding is therefore connected directly across the line. The control for a wound rotor type of induction motor must care for both primary and

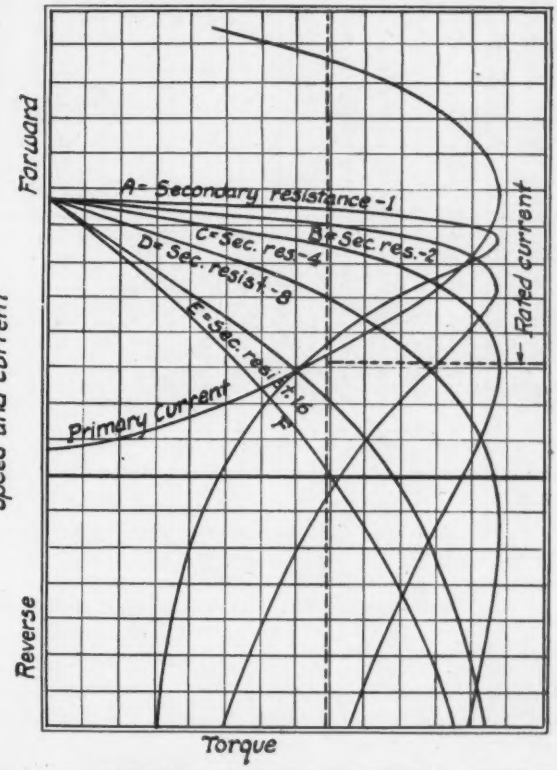


FIG. 1. SPEED-TORQUE AND CURRENT CURVES OF AN INDUCTION MOTOR WITH VARIED SECONDARY RESISTANCE

secondary circuits. It must provide a means for connecting and disconnecting the primary winding from the source of power and it must provide a means for varying the secondary resistance.

DETERMINATION OF SECONDARY RESISTANCE

In order to calculate the secondary resistance for a wound rotor induction motor, the locked rotor volts and full load secondary amperes must be known. If only the locked rotor voltage is known, the full load secondary current may be found by use of the formula:

$$I_r = \frac{\text{H.P.} \times 746}{E_s \times 1.73 \times (1 - \text{slip})}$$

Where I_r = full load secondary current.
H. P. = rated horsepower of the motor.
E_s = locked secondary volts.
slip refers to that at rated speed with full load.

In general the procedure in the determination of secondary resistance for a wound rotor induction motor is similar to that for direct current motors. The allowable primary current inrush is determined, taking into consideration the torque demanded by the load. The secondary resistance supplied is somewhat greater than that giving maximum torque at standstill. Thus the starting condition is exemplified in general, by regulation curve E, or F, Fig. 1. In Table I are shown approximate values of torques developed for various initial primary current values.

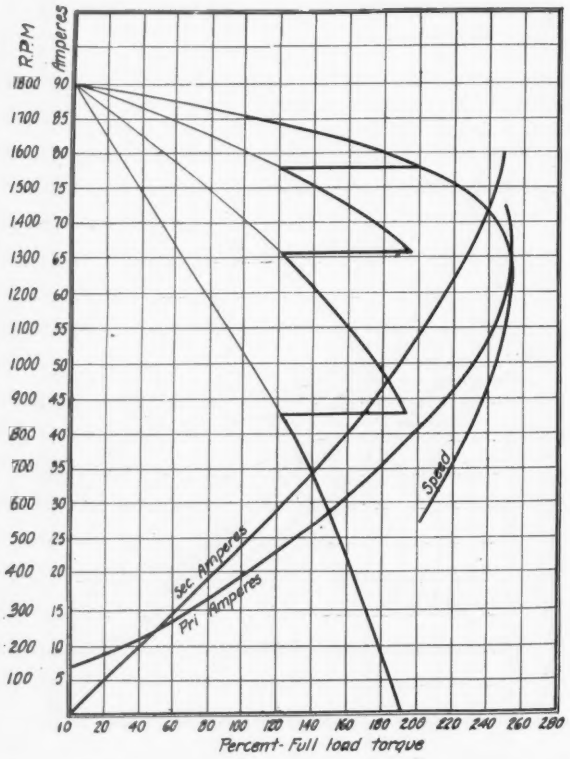


FIG. 2. TORQUE DEVELOPED DURING ACCELERATIONS OF A WOUND ROTOR INDUCTION MOTOR. SECONDARY RESISTOR CUT OUT IN THREE STEPS

To determine the balanced three-phase secondary resistance of Y connected wound rotor induction motors, the following formula may be used:

$$R = \frac{E_s}{1.73 \times I_r} \times \left(\frac{100}{T_1} - 0.10 \right)$$

Where R = external resistance per leg of the Y, ohms.
E_s = locked secondary volts.
I_r = full load secondary current.
T_1 = torque developed on first point of controller, expressed in per cent of full load torque.

The expression $\frac{-0.10 \times E_s}{1.73 \times I_r}$ is included as a deduction for resistance and reactance of rotor winding and leads.

Based on this formula, the resistance values shown in Table I are obtained.

Secondary resistors for wound rotor motors are usually Y connected. Sometimes the delta connection is used in order to reduce the current handled by the controller fingers. If the resistance is delta connected, determine the proper value of Y connected resistance and multiply by 3 to get the proper resistance of each leg of the delta. The current in each leg of the delta connected resistance is the motor secondary current divided by 1.73. The principles governing the subdivision of resistance into steps are similar for direct and alternating current motors. The principles outlined in the article on page 827 of the Aug. 15 issue may be employed in connection with wound rotor induction motors. Figure 11 is of interest in showing the similarity between the direct current motor and the wound rotor induction motor in accelerating characteristics. This figure shows the torque developed during acceleration of a wound rotor induction motor with the secondary resistor cut out in three steps. The values of primary and secondary current for any torque value are shown, these being independent of the secondary resistance. A little study will show that, in starting from rest, a primary current of 38 amp. is taken; this falls to 23.5 amp. as the motor accelerates. The first section of the resistor is then short circuited and the primary current increases again to 38 amp. and falls off again with further acceleration until the next section of the resistor is short circuited, when the current falls to 23.5 amp., etc. The similarity to Fig. 1 on page 732 of the July 15 issue of Power Plant Engineering should be evident.

TABLE I. VALUES OF THREE-PHASE Y CONNECTED SECONDARY RESISTANCE

Primary current inrush, first point. % full load current	Starting torque developed % full load torque	R = resistance per leg of Y. Ohms
50	30	$1.87 \frac{E_s}{I_r}$
70	50	1.10 "
100	100	0.52 "
150	150	0.33 "
200	200	0.23 "

Where a wound rotor induction motor is subject to plugging service, an additional external resistor is desirable to reduce the plugging torque and current, just as with the direct current motor.

SINGLE-PHASE SECONDARY REDUCES TORQUE

If single-phase secondary starting is employed, the torque developed with given current input is reduced to about one-half that obtained with balanced three-phase secondary resistors. Conversely, the primary current input required to develop a given torque with single-phase secondary is about 167 per cent of that necessary with balanced three-phase secondary.

Resistor values to be used for single-phase secondary starting duty may be taken from Table II.

This method of starting should not be employed when more than full load starting torque is desired, due to the heavy starting current taken.

As its name implies, the synchronous motor is operative only at synchronous speed. At standstill it has no

torque produced by synchronous motor action. It is necessary to accelerate motors of this type to approximately synchronous speed before they become operative as synchronous motors. If this is done by means of an auxiliary motor or another unit, the control for the synchronous motor becomes merely a means for switching the synchronous motor onto its system when the condition of synchronism is reached, together with means to indicate this synchronous condition and means to control the direct current for the fields.

TABLE II. VALUES OF RESISTANCE FOR STARTING WITH SINGLE-PHASE SECONDARY

Primary current inrush, first point. % full load current	Starting torque developed % full load torque	R = resistance per leg of Y. Ohms
84	30	$0.95 - \frac{E_s}{I_r}$
117	50	0.54 "
167	100	0.24 "

In the case of the so-called "self starting" synchronous motor, starting effort is secured entirely by induction motor action. Self starting synchronous motors are provided with a squirrel cage winding on the rotor. This winding is employed to transform the motor, during the starting period, into a modified squirrel cage induction motor. To start a motor of this type it is the common practice to connect its primary or stator winding across a reduced potential just as is done in the case of the squirrel cage induction motor. This reduced voltage may be secured by any of the methods employed in providing reduced starting voltages for induction motors. The control for a synchronous motor of the "self starting" type comprises: a means for connecting the primary first across a reduced voltage and then across full voltage; a means for connecting the fields across a resistance during the starting period and to their direct current source after the motor has accelerated; a means for adjusting the motor field strength; instruments and protective features as required.

To Control Direction of Rotation

The direction of rotation of a multiphase induction motor, of either squirrel cage or wound rotor type, and that of a synchronous motor, as well, is governed by the direction of rotation of the revolving field about the stator bore. This revolving field is set up by currents, out of phase with each other, passing through coils so located that the flux travels around the stator as the coils are successively energized. It is evident that a certain sequence of currents passing through a given sequence of coils, will cause the flux to travel in one manner. A different sequence of currents, passing through the same sequence of coils, will cause the flux to travel in a different manner. Interchange of two primary leads of a three-phase motor causes the currents in the coils of these two phases to reach their crest values at interchanged periods with reference to the crest current in the third phase. This reverses the direction of travel of the flux from coil to coil, reversing the direction of the revolving field. Reversing the revolving field causes the rotor to follow behind the revolving field in the reverse direction. To reverse the rotation of a three-phase motor it is only necessary to interchange any two of the three primary leads. To reverse a two-phase motor the two primary leads of either phase must be interchanged.

Reversing Duty

Most induction motors and nearly all synchronous motors are operated in a single direction determined at the time of installation. Direction of rotation is then merely a matter of connections. Some induction motors are called upon to run in reverse direction only occasionally, as for a backing off operation. In such cases, some type of throw-over switch is commonly installed to reverse the primary leads while the motor is at rest. It is then started in the reverse direction in a normal manner. Actual "reversing duty" is required of but a small minority of induction motors.

Reversing duty may be successfully handled by specially designed squirrel cage motors, having high rotor resistance. The control comprises a primary switching device for reversing connections, together with means for supplying reduced primary voltage during reversal and acceleration. This type of control is little used except where simplicity of wiring is of advantage, as in the case of traveling cranes.

To Control the Direction of Torque

The torque of an induction motor is ordinarily exerted in the direction that the revolving field rotates. If the load overhauls or tends to drive the motor above synchronous speed the motor becomes an induction generator and exerts a negative torque against the direction of rotation and against the revolving field. If a motor be "plugged" by reversal of the primary leads while the rotor is in motion, the direction of rotation of the field is reversed. The motor exerts a negative torque against its motion until the rotor comes to rest following which it immediately reverses and tends to accelerate in the direction of the revolving field.

Dynamic braking, which consists in providing a negative or a restraining torque to bring a motor to rest, cannot be accomplished with the induction motor as simply as with the direct current motor. It is accomplished by disconnecting the motor primary from the alternating power and exciting the primary winding with a low voltage direct current. This may be obtained from a suitable direct current source or from an exciter connected with the motor. The effect is to create a stationary magnetic field in the stator core. As the closed circuited rotor revolves through this field a voltage is generated within it, setting up currents which react to produce a torque opposing rotation, through simple generator action. The stronger the fixed flux, the greater the braking torque. The lower the resistance in the rotor circuit, the greater the current flow and the greater the braking torque.

Synchronous and induction motors are essentially constant speed machines. The speed of rotation of a synchronous motor is constant and cannot be varied except through variation of frequency of the circuit from which the motor is operated. The induction motor is also primarily a constant speed machine. It does not lend itself to speed adjustment nearly so well as the direct current motor. For a restricted range of application, the speed may be so controlled as to meet the requirements of the drive.

Variable Frequency

It is possible to vary the speed of an induction motor by varying the frequency of the circuit upon which it operates. This requires that the generator speed be varied or that a frequency changer be employed. The voltage should be varied as the frequency is changed as an increase in frequency has indirect influence similar to a decrease in voltage.

Multi-Speed Motors

In an induction motor the rate of rotation of the revolving field is determined by the number of poles per phase in the stator or primary winding. By changing the coil connections the number of poles per phase may be doubled. The synchronous speed is then halved. In some motors, two primary windings are provided in the stator, wound to give a different number of poles. The synchronous speed of the motor then depends upon the

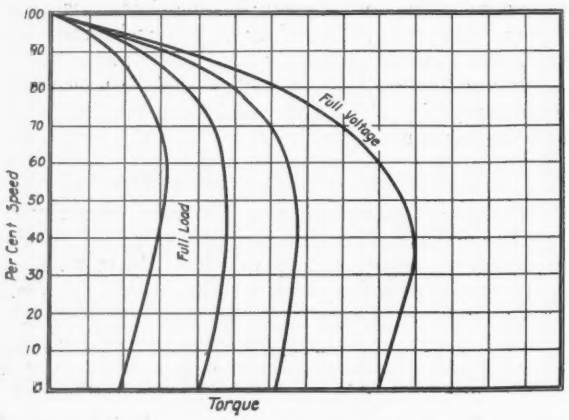


FIG. 3. SPEED TORQUE CURVES OF INDUCTION MOTOR WITH VARIED PRIMARY VOLTAGE

winding used. These so-called "multi-speed" motors are usually of the squirrel cage type.

Secondary Resistance Control

Speed regulation of an induction motor depends upon the resistance in the secondary circuit. The greater the secondary resistance, the greater the "slip" below synchronous speed with a given load. By introducing resistance in the secondary circuit of a wound rotor motor, a range of speed down to 30 to 50 per cent below synchronous speed may be obtained. The characteristics are analogous to those of the direct current motor with armature control. The controller may be of any type capable of adjusting the secondary resistance. Since the motor speed, for a given value of secondary resistance, varies with the load, the speeds may be called varying rather than adjustable. This type of motor and speed control are suited only where the load is comparatively steady, where speed regulation is not important or where continuous manual adjustment is possible.

Primary Resistance Control

The slip of an induction motor under load varies approximately inversely as the square of the applied primary voltage. It is therefore possible to control the speed of squirrel cage induction motor by changing the primary voltage applied at its terminals. Standard squirrel cage motors are not suited for this work as their torque, with reduced voltage, is comparatively low. Specially designed motors, having low magnetic leakage and high rotor resistance, may be successfully controlled by this method over a limited speed range.

Inasmuch as motors adapted for this method of speed control must have a comparatively high rotor resistance, it follows that, even with full primary voltage, there will be considerable slip. Motors of this type will run at 85 to 90 per cent of synchronous speed under full load with full primary voltage. Figure 3 shows the characteristics obtained by this method at different values of primary voltage. At full voltage the slip is 11 per cent at full load.

Cascade Sets

Induction motors may be operated in series parallel or cascade to provide a selection of speeds. In this arrangement, one motor must be of the wound rotor type. The second motor may be connected to the secondary of the first motor. If both motors are connected for the same number of poles, operation in series or cascade will give a half speed point. The motors may also be operated singly or in parallel to give full speed. The control for a cascade set is similar to that for the individual motors with additional switches for connecting the secondary of the first motor either to resistors or to the primary of the second motor.

Power to the Farm

PROFITABLE business has been secured by some central stations, which have transmission lines passing through farming districts, in furnishing electricity to the farms for lighting and for driving saws, churns, separators, feed cutters and other machinery. The power part of this load comes largely in the months when city load is lightest, hence fills in well to use idle station capacity.

Now comes a trial of a distinctly rural transmission line, built especially to give that service. One objection to the previous practice is the losses in comparatively small transformers to tap high-voltage transmission lines, and the high initial cost per kilowatt capacity for such transformers. In the trial to be made in Minnesota by the Northern States Power Co., a low voltage distribution line is to be run from the nearest town having a transformer station.

It is proposed to erect a line 5 mi. long from West Concord to the farm of Isaac Emerson, 15 farms along the way being possible customers. Cost of this line and the small transformers for tapping it may be borne by the farmers or by the company as they may agree. In the first case, the company will charge no interest on investment for the line.

Each farmer is to be given 3 kw. or 4 hp. of demand capacity and will be charged for interest, depreciation, maintenance, taxes and insurance on the generating machinery needed to supply him. This is a "ready to serve" charge, and to it will be added the charge for taxes, insurance, depreciation and maintenance on the line and service transformers; also interest, if the company builds the line. Low voltage lines from the roadway to the farm buildings, as well as wiring for buildings are installed by the farmers, but the company installs and pays for the meter.

Meter reading, bookkeeping, "shooting trouble" and transformer losses are charged at $1 a month. Total fixed charges are estimated, for the West Concord line, if all 15 of the farmers join in, at $4.76 a month, per customer, the customers building the line, or $6.90 if the company builds it.

For consumption charges, the rate is to be 5 cents for the first 30 kw.-hr., and 3 cents for additional use. Adding fixed charges, this makes the kw.-hr. rate high if only little current is used, but the total cost per kw.-hr. drops rapidly as use becomes greater. For 20 kw.-hr. a month, the cost would be at a 39.5 cent rate, for 50 kw.-hr., at an 18 cent rate; for 100 kw.-hr., at 10.5 cents; for 200 kw.-hr., at 6.7 cents, and for 300 kw.-hr. at 5.5 cents. It is probable that on most farms the use would be such as to result in a rate between 6.7 cents and 10.5 cents, which compares favorably with the cost of current to suburban and small urban customers.

If all 15 of the farmers do not join in, the cost will, of course, be greater per kw.-hr. and on a line where more farms could be served, that cost would be less.

If this plan can be worked out satisfactorily to the company and the farmers, it would seem to open a large field for central station service, and provide the farmer with a more satisfactory power than the small gasoline engine at a cost at least as low, probably lower than that for the power service.

Successful Repair of Commutators

THE PRACTICE OF TURNING DOWN COMMUTATORS IS WASTEFUL AND SHOULD BE AVOIDED WHEREVER POSSIBLE. BY A. R. KNAPP

EVERY MAN in charge of the operation of electrical machinery should be able to repair successfully the commutators of direct current motors and generators. The term "successfully" is used here for the reason that there are many men who are able to do passable work on a simple job, but when they meet with something in the least bit difficult, they give up and have the work done outside. This is not only expensive, but often requires that the machine be out of service for a long time.

Practically every repair from a simple burnout to a refilling job can be successfully accomplished in the average industrial plant workshop and any operator who is willing to expend the necessary energy can obtain the same results as the outside repair shops. A lathe is the only machine tool necessary, although a milling machine or shaper is often useful.

When a commutator has developed a number of bad mica segments, the temptation to turn the commutator down until the burnt mica is eliminated, is hard to overcome. Don't do it. To save the wearing surface will more than compensate one for the work involved in replacing mica segments. The writer was once employed by an electrical manufacturer who also did repairing. Numerous jobs that were sent in to be repaired were never repaired at all. The foreman would take a look at the work, and if he decided that the burns were not too deep, the commutator would be turned until the mica showed clear. In many instances, ¼ in. of perfectly good wearing surface was often cut off the diameter, representing perhaps 5 yr. or more useful service. Luckily not all shops use such methods of repairing. The foregoing example is sufficient reason for every industrial plant to be equipped to do its own repairing, and to employ a man capable of doing good work.

When a commutator has several burnt mica segments, it can usually be repaired without removing the armature. Take a thin bladed knife and carefully dig out all the charred mica. Make sure all the black is removed, and that the mica shows clear to the bottom of the burn. Then plug the holes with a commutator cement. There are several different makes of this cement on the market. A first-class cement can be made by mixing two parts plaster paris, one part powdered mica, and enough wood glue to make a thick paste. This compound has been used by the writer for a number of years, and has given uniformly good results. It is always good business to save the wearing surface in this manner as long as plugging will hold.

There are exceptions to almost every rule, and the following may be noted. In the case of fractional horsepower motors, fan motors, and the like, it is often advisable to turn down the commutator rather than attempt to insert new mica segments. The constructional design of fractional horsepower commutators is such that it is almost impossible to get them back to a cylindrical shape. Unless the shop is equipped with a clamp for each different size of small commutator on hand, it will often be found just as economical to turn the commutator.

When new mica segments are to be inserted, clean the commutator and armature thoroughly with compressed air, especially the back end of the commutator behind the risers or lugs. Number the copper bar on one side of each burnout, as they may have to be taken out in order to remove the bad segment. Loosen the nut or bolts holding the end ring in place. Mark the ring so that it can be put back in exactly the same position. Tap it lightly with a hammer. If it does not spring loose from the copper, it is probably stuck tight with shellac. In this event, heat the copper with a blow torch until the expansion of the copper will push the ring free. Pry the bars apart slightly at each burnout. If the mica sticks to the copper, the numbered bars should be unsoldered and taken out.

Scrape and file these bars smooth, being sure to round off all sharp edges. Use one of the bars to lay off the new mica segments. They can be cut a little full, and the segments and copper bar clamped in a vise and the mica filed to accurate size. Leave the segments about ⅛ in. oversize all over except the clamping ring edges.

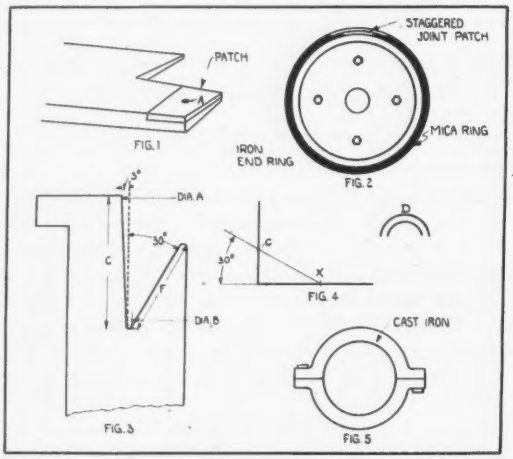
Make sure that the back end of the clamping ring sleeve is clean, and that no dirt, solder, or other foreign material is lodged there. Insert the mica segments first, then push in the bar. When all the segments and bars are replaced, inspect the mica end ring and see that it is clean and free from burnt spots. Also inspect the inside of the commutator. Replace the ring and draw up evenly on the bolts. Go around the commutator with a light hammer, and see that all the bars and mica segments are down against the end ring. Paint the end

ring and the edges of the new segments with a good grade of shellac to fill any small cracks that may exist.

Now heat the commutator with a torch until moderately hot, and tighten the bolts. Continue the heating until sure that all the moisture has been baked from the shellac. Draw up the bolts again firmly. Be careful not to heat to the point of melting the solder from the coil connections, or from the risers where they are soldered into the bars. When the commutator is cold, give it a final setting up.

Repairing Bars and Mica Rings

Often a bar will have a hole burned into it of such proportions that a repair will have to be made, or a new bar obtained. A repair in this case can be made as shown in Fig. 1. The burnt place should be cut out in a milling machine or shaper as shown in the cut. A sharp file will also serve the purpose. Solder a strip of



FIGS. 1—5. DETAILS OF METHODS USED IN MAKING COMMUTATOR REPAIRS

copper into this cut and file to the proportions of the bar. The patch should also be riveted on as shown at A in order to prevent it from flying out should the commutator for any reason become hot enough to melt the solder.

Repairs to the mica end rings are often necessary. It is not difficult to make a good repair on these rings, and it is much cheaper than replacing the entire ring. Grounded armatures are often the result of holes being burned through the end ring, grounding the armature with the iron work of the machine. A first-class repair can be made as shown in Fig. 2. Cut out the bad mica by sawing through the ring, and insert a patch with staggered joints. See that the patch is a trifle thicker than the old ring, as the new mica will squeeze together somewhat. Replace the end ring in the commutator, and apply shellac to the ring as mentioned before. Heat the commutator with a torch until the patch is thoroughly baked.

It may be that the mica rings are in such poor shape that new ones must be made. These also can be made up in the plant repair shop. The material for these rings is flexible mica, usually 0.030 in. in thickness. When heated slightly on a hot plate, this mica can be bent to any desired shape. Figure 3 shows the usual design of a commutator bar.

To make a template for laying out the rings, proceed as follows: with a radius equal to the diameter of the commutator bore A, Fig. 3, strike an arc of a circle on a piece of cardboard. From the same center strike another arc with the dividers made smaller by the distance C. This will provide a template for the ring I. Cut the template for length so that it will equal one-third the circumference of the ring.

For the taper along F, take one-half the diameter B, and lay off one-half this distance on horizontal line Fig. 4, as at X. With a protractor lay off the line XC, 30 deg. from the horizontal. With XC as a radius, strike the arc of a circle D. With the radius made smaller by the distance F, Fig. 3, strike another arc from the same center.

When a refilling job is necessary, first remove the commutator from the armature shaft. Count the bars carefully and make a note of this. Take the commutator apart, and measure in thousandths of an inch with a micrometer the thick and thin edges of a bar. Also measure accurately the thickness of a mica segment. This will usually be 0.030 in. Copper bars can be obtained from the motor manufacturer sawed to a rough size ready for boring.

To assemble the commutator properly, a clamp must be used. A good clamp for the average size commutator is shown in Fig. 5. This can be made in the shop at small expense. The clamp should be bored to a diameter slightly smaller than the full diameter of the commutator, so that when clamp is drawn tight it will not close.

Set the clamp on a face plate so that the bars and mica can be placed within it. Space the clamp about midway of the bars by using small wooden blocks. When all segments are in place, tighten the clamp sufficiently to hold the bar rigid. Place a bare copper wire about the top and bottom of the commutator, and tighten. Now remove the clamp, and bring the mica segments out even with the copper by tapping the bars lightly and holding the fingers against the mica on the inside. Straighten the bars perpendicularly by use of a small steel square placed on the face-plate. Tap the bars and mica segments down against the face-plate. Now replace the clamp, and tighten thoroughly. Place the commutator over a gas jet or some source of heat, and heat fairly hot. Tighten the clamp, and allow it to cool. When cold, again tighten the clamp.

Now clamp the commutator to the face-plate of the lathe, and center it carefully. If the old mica end rings are to be used again, bore the commutator ends to fit these rings. With a bevel protractor obtain the exact tapers used on the old bars. Bore both ends to these exact tapers. When the machine work is finished, carefully examine the machined surfaces. Copper is frequently dragged over the mica, producing a short-circuit. When certain that the mica segments are clear, the sleeve may be replaced. Carefully wipe out the commutator with a soft cloth, and scrape and clean the end rings thoroughly. Fill any cracks that may exist between the end rings and copper by pushing in thin slivers of mica. Use plenty of shellac on the ends.

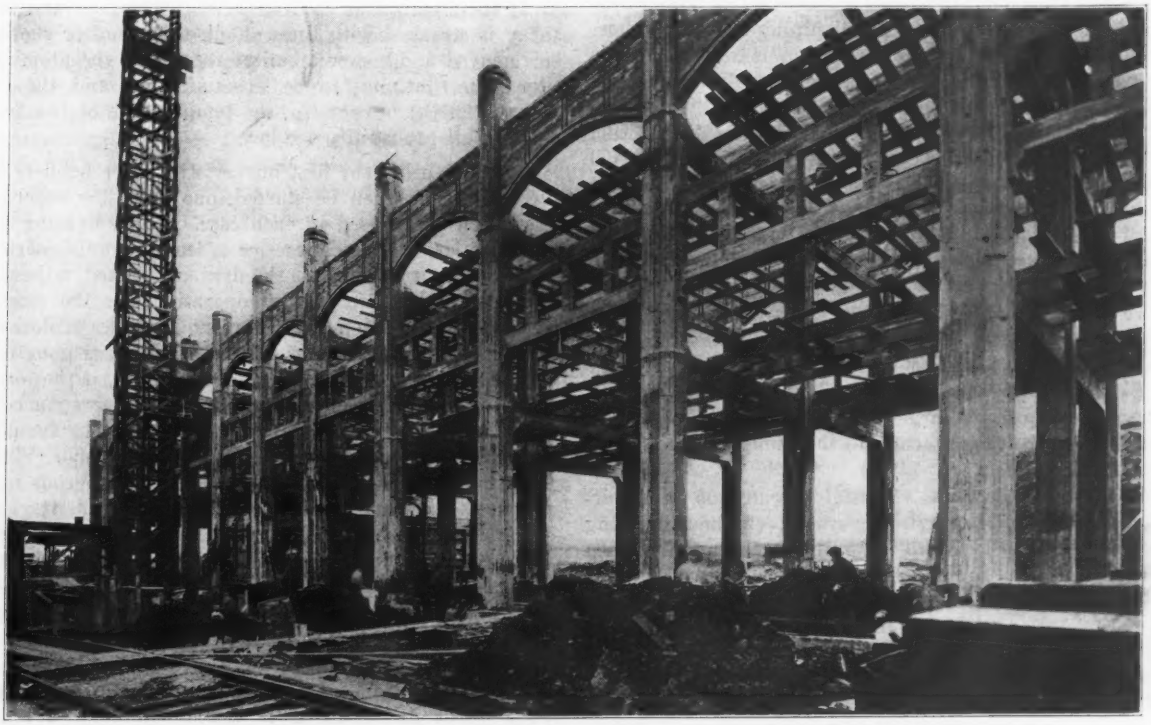
Heat the commutator until hot, and tighten the bolts. Reduce the heat somewhat, and bake until the shellac is dry. Tighten the bolts again, and allow to cool. When cold, try the bolts again.

The commutator should now be given a bar to bar test for short-circuits, also a test for grounds. If found to show clear, it can be replaced on the shaft, and the wearing surface turned true with the shaft centers.

First Concrete Switch Structure at Crawford

CONCRETE TRANMISSION STATION AT CRAWFORD STATION OF THE COMMONWEALTH EDISON CO. HARMONIZES ARCHITECTURALLY WITH THE GENERAL DESIGN OF BUILDINGS

IN THE accompanying photograph is shown a view of the new reinforced concrete outdoor transmission station recently completed at the Crawford Avenue generating station of the Commonwealth Edison Co., of Chicago, now under construction. This structure, the first of its kind ever constructed, was built of concrete for three reasons, foremost among which was the matter of appearance.



FIRST CONCRETE OUTDOOR TRANSMISSION STATION AT CRAWFORD

No matter how correct from an engineering viewpoint, steel outdoor switching stations as they have heretofore been constructed have not been endowed with a great amount of architectural beauty. Where such structures have been located in remote districts, away from the cities, their architectural appearance has, of course, been a factor of minor importance, and it is natural that little attention should have been paid to this phase of the question. When such structures are built in cities, however, appearance becomes a more important factor and in the building of Crawford station, where considerable effort has been expended in making the station architecturally attractive, the engineers of the Commonwealth Edison Co. sought to secure a design for a switch structure which would harmonize with the other structures comprising the plant.

Concrete offered the greatest opportunity for architectural expression, and after considering the matter from various angles, it was finally decided to build the new transmission station of reinforced concrete. While concrete was selected mainly for appearance it has other advantages. In the first place, it requires less maintenance, and, therefore, lower maintenance costs. Furthermore, its construction is not affected by the time required for the delivery of fabricated steel. The latter is an important point, since the switch structure is to be the first part of the plant as a whole to be put in service, and as its design is dependent upon the electrical features of the system, it was found that there would not be sufficient time after the completion of the electrical design to allow for the usual delay in fabricated steel deliveries. So, for more reasons than one, concrete was the most desirable material.

The ultimate purpose of this structure, is to serve as a transmission station for Crawford. Crawford is to be the "backbone" of the Commonwealth Edison system, and will transmit current to other stations through this switch structure.

Until the completion of the Crawford station, however, which will not be for another year, the switch structure will serve as a switching center for distributing current from the various other stations on the system.

Transformer equipment consists of four 15,000-kv.a. transformers, 12,000 v. delta connected, 33,000 v. star connected, fitted with ratio adjusters on the high voltage side. These ratio adjusters enable the power to be fed through the transformers in either direction.

The photograph shown on this page was taken by A. R. Gerlach, official photographer of the Commonwealth Edison Co., and is reproduced herewith by special permission.

Mechanical Atomization of Fuel Oil---II

FACTORS INVOLVED IN THE CORRECT OPERATION OF THE MECHANICAL ATOMIZER TYPE OF OIL BURNER ARE DISCUSSED. BY CLAUDE C. BROWN

IN STARTING up a boiler equipped with the mechanical atomizing type of oil burning apparatus first be sure that all of the burner atomizers have had their initial and correct adjustments, and that all joints are tight. Be sure, also, that all of the atomizers are thoroughly clean and that there will be no danger of poor atomization because of plugged strainers or because chips or pieces of waste or other foreign matter have become lodged in the oil passages of the apparatus. Before and after installation all piping should be thoroughly blown out with air or steam before any oil is put into the system. Also be sure that all valves leading to the different burners have been closed. If reciprocating pumps are used for the handling of the fuel oil, and an air cushion cylinder is provided in the fuel oil line, have the necessary connections made so that this air cylinder may be charged with air after the fuel oil is started through the system. It is necessary that the fluctuations in the pressure of the oil from the pump be eliminated as far as possible by the air cushion before the first burner is lighted. As a matter of fact, it has been found in a number of installations that the best results have been obtained by the use of a rotary oil pump equipped with air cushion chambers on both the suction and discharge sides of the pump, especially in cases where the oil comes to the pump under gravity pressure.

Having taken these essential precautions, start circulating the oil through the system (without lighting any of the burners) until the piping is thoroughly warm and the fuel oil has reached a temperature at which it should be possible to obtain satisfactory atomization. Needless to say, all oil piping, heaters and other apparatus should be covered and insulated in order that the losses in heat due to radiation may be minimized.

LIGHTING THE FIRE

Having secured a satisfactory temperature of the oil in the system, a lighted torch (one made of asbestos rope, soaked in oil and fastened to the end of a stiff wire or rod may be used) should be inserted through the wide open doors of the register of the burner which is to be lighted, all other burners having their doors closed. The damper of the boiler should be wide open during this lighting up process, in order that all gases and smoke will be quickly removed. The torch should be held close to the tip of the atomizer so that its flame will play freely around the latter. The valves in the oil line leading to the burner should then be opened, the last one being opened gradually. As the fuel oil issues from the tip of the atomizer, in a finely divided spray, the flame from the torch will ignite it and it should continue to burn with a dull, roaring sound, provided the atomizer is clean and producing the right spray and the temperature of the oil is correct.

If the atomizer is dirty or if there is any water in the oil, a decided sputtering and an uneven flow of oil will result. If the trouble is due simply to a quantity of water in the oil, the water will soon pass through and the dry oil will atomize properly. The torch should be held near the tip of the atomizer until all of this water has disappeared, and there is no danger of the flame going out. Such precaution will eliminate the possibility of a violent explosion when the oil starts coming again and strikes the hot brickwork of the furnace. If the oil comes intermittently, there is in all probability a stoppage somewhere in the system. It may be either in the strainers, in the heaters, in the piping or in the atomizer itself.

If the atomization continues noticeably poor and the spray is streaked with lines of oil, the atomizer should be removed and a new atomizer fitted. If the atomization then continues to be unsatisfactory and the oil drips from the burner tip, the temperature of the fuel oil is in all probability too low.

After lighting the first burner, the other burners in the boiler may then be started, one after the other, a new torch being used in each case. When lighting up a cold boiler, it is good practice to leave a torch inserted at each burner until all of the fires are lighted, adjusted and settled down to regular operation, for the reason that such precaution may prevent possible explosions caused by unburned gases from a fire having gone out while the others were being lighted. Again, if the torch is not used with each burner when starting up a cold boiler, a large quantity of oil may get into the furnace before the burner will light up from its neighbor. This unburned oil in the furnace produces a dangerous condition, as in striking the warm floor and walls it gives out volatile gases which make an explosive mixture with the air in the furnace. The ignition of this mixture is capable of producing a violent explosion which may damage the apparatus and possibly cause serious injury to the operators. For that reason, care should be taken to insure the immediate lighting of a burner as soon as the oil is turned on. In one instance on record, a complete boiler and economizer were completely wrecked by the explosion of gases formed in them by the burners going out and relighting from the heated brickwork.

It is not good practice to raise the steam pressure in a boiler too suddenly if it can be avoided, as frequent repetitions of this practice, due to the sudden changes in temperature, tend to produce expansion and contraction strains that crack and loosen the brickwork and furnace lining. In raising steam in a boiler, it is advisable to use the small capacity tips which are provided with forced draft jobs and to begin with natural draft.

When lighting up a cold boiler, the cast-iron impeller and cone will be cold, so that any oil striking them from the atomizer tip will collect inside of the register and run down the boiler front plate. In order to prevent this condition, the center impeller and the atomizer should be pushed in far enough so that the atomized oil spray clears the bladed cone. It will be found that as the furnace and the cone warms up, the atomizer may be gradually pulled out from the furnace, and any small amount of fuel oil that strikes the cast-iron blade cone will be burned off. After the cone is thoroughly heated up, the center impeller and strainer should always be pulled out.

Adjustment of Air Supply

After the boiler has been cut into the main line and is steaming steadily, the supply of air for combustion should be adjusted to allow just sufficient air to pass to give satisfactory combustion. If sufficient air of combustion is not supplied to take care of the amount of oil being delivered by the atomizers, the effect may be noted in the fireroom in a number of ways. If the lack of air is decided, pulsations will be set up in the furnace and a dense black smoke will issue from the stack. If the lack of air is not sufficient to produce pulsations, it will at least produce heavy smoke, which may be detected through the peephole in the bottom of the third pass of the boiler or by the appearance of the flame observed through the furnace peephole. This heavy black smoke, if allowed to continue, will not only be bothersome to the neighborhood, but will in addition leave carbon and sulphur deposits on the boiler tubes. The carbon forms on the tubes in a hard cake which is difficult to remove and which acts as an insulator, preventing the heat from the gases of the furnace from being transmitted through the tubes to the boiler water.

Lack of sufficient air for combustion will also produce carbon monoxide in the gases of combustion, resulting in a large loss of boiler efficiency. The CO thus formed goes out through the stack as a combustible gas unconsumed. Had there been sufficient air and oxygen for proper combustion, the gas would never have been formed or in case it was formed would have further united with the oxygen of the air to form CO_2.

If the blowers are delivering all of the air which can be obtained from them at the time that pulsations and black smoke are produced, the only remedy is to reduce the amount of fuel oil being delivered to the burners, either by a reduction of the fuel oil pressure or the cutting out of a number of burners. Allowing the fuel oil to go into the furnace when there is not sufficient air to burn all of it properly, will not assist in holding the steam pressure up at the point at which it should be maintained, but will produce a heavy black smoke which will, in fact, leave such a coating of heavy soot on the boiler tubes, that an actual lowering of the rate of evaporation of the boiler will result. This, of course, lessens the ability to raise the steam pressure and allows the steam pressure to drop still further.

When too much air is used, an even greater falling off in boiler efficiency and boiler capacity will take place. This excess air, being more than is needed for the proper combustion of the fuel oil in the furnace, performs no service in the combustion of the oil but simply passes through the furnace, lowering the temperature of the latter, becomes heated to the resulting furnace temperature and carries its heat on out the stack. In addition to this, the excess air greatly increases the volume of the furnace gases so that the gas passages of boiler, economizer and stack are called upon to handle this excess which often taxes their capacity as well as cuts down the available draft and increases the velocity of the gases. Indications of excess air are a perfectly clear stack (or gas as viewed through the bottom of the third pass peephole), and a short flame in the furnace of a dazzling white appearance.

If a decided excess amount of air is used, a large loss also is occasioned by the fact that the entire furnace and the flame coming from the burner tips are chilled to the point where it is impossible for the combustion of the fuel oil to be completed, because of its low temperature, with the result that the white smoke of unconsumed gases passes out the stack. The extreme use of excess air and the corresponding chilling of the brickwork is also likely to result in the formation of heavy carbon deposits on the furnace walls and the floor, which would not take place if the furnace walls and floor were at their proper temperature. The following approximate table shows the relation of the boiler efficiency to the amount of excess air used (at rating):

Per cent excess air	10	50	75	100	150	200
Per cent boiler efficiency..	80	76	73	71	65	60

Natural vs. Forced Draft

In the case of mechanical atomizing apparatus it should be noted that the burners of the standard makes of equipment may be operated under either natural or forced draft conditions. If the proper care is exercised in operation, the efficiency of the burner may be made the same under both of these conditions, that is, the percentage of carbon dioxide in the uptake gases may be kept at a maximum regardless of the type of draft used.

In the operation of the mechanical atomizing apparatus, the adjustment of the air doors should be carefully checked up on all burners to make sure that it is uniform throughout. Under ordinary steaming conditions with forced draft the most satisfactory operation is obtained with the air doors a little less than one-third open.

To obtain maximum capacity under natural draft conditions, the air doors should be left wide open. If dampers are not used in the boiler uptakes and the steam requirements do not call for the maximum natural draft capacity, the amount of air entering the burners can be reduced by partly closing the air doors, the degree of closing being dependent upon and governed by the amount of fuel oil being delivered by each atomizer. By regulating the doors in this way, the combustion may be maintained at a high standard even when operating at fractional loads and at the lowest rates of oil consumption per burner.

In this type of apparatus the tension of the springs on the air doors should be such that all doors on the register will open wide whenever the door handle is at its extreme throw, but at the same time this tension should not be great enough to prevent the automatic closing of the air doors in case of a flare-back or the bursting of a tube in the furnace. If, due to careless operation, any fuel oil is allowed to collect in the bottom of the register, it will soon form a heavy black tarry deposit on the inside of the register, which, if not cleaned off, will interfere with the proper operation of the lower door in the register. For this reason, particular care should be taken to inspect the lower air door in each register and to be sure that it opens freely and to its maximum width. All of the air doors in a register should be open an equal amount when a burner is in service. This is important as it has a direct effect upon the distribution of both the air and the oil spray and if the air stream is greatly distorted by unequal door openings the flame will be thrown out of center and serious results may occur.

The adjustment of the center impeller in and out along the axis of the atomizer is primarily for the purpose of controlling pulsations in the furnace at the

higher drafts. For ordinary operation at low ratings the center impeller can be pulled back until the plane of its outer edge is practically in the plane of the front plate of the boiler. This is the natural draft position for this impeller.

Should pulsations be experienced when using this apparatus at higher drafts with the center impeller in the natural draft position, pushing the impeller and the atomizer in toward the furnace will reduce these pulsations and if continued far enough, will entirely eliminate them. It is obviously not desirable to push the impeller in toward the furnace farther than necessary to eliminate the pulsations, as this rapidly cuts down the air supply available for the burner, with consequent reduction in the capacity of that burner. In service it will probably not be found necessary to push the center impeller in more than one inch from its natural draft position in order to control pulsations. This limitation, of course, does not apply when the boiler is first being lighted up, as in that case it may be necessary to push the center impeller all the way in in order to keep the atomizer from spraying an excessive amount of fuel oil on the cast-iron bladed cone.

Operation Under Reduced Load

One important point to remember when operating a boiler with a number of mechanical atomizers shut off, is to keep the atomizers and the center impellers of the burners that are not in service pulled out to at least the natural draft position and preferably a little farther, to prevent the overheating of the atomizer tips and the cast-iron center impellers from the radiant heat of the furnace. The air doors of any burners that are not in service should be kept closed so as not to admit any cold air into the furnace through them.

When selecting burners for carrying a given load, they should be arranged across the boiler front so as to maintain as uniform a flame distribution as possible throughout the furnace. A few burners should not be lighted in one spot so that a small portion of the boiler heating surface will receive all of the hot gases while the remainder of the boiler is practically cold. It is much better when running under less than full load conditions, to operate a larger number of burners at a lower oil pressure (around 100 lb. per sq. in.) than to use but a few burners at a higher fuel oil pressure (200 lb. or more). A further advantage of using a larger number of burners at a lower oil pressure is the reduced air pressure which it will be found necessary to maintain in order properly to burn the same amount of fuel oil per boiler per hour.

More trouble is experienced with oil burning systems because of fluctuations in the pressure of the fuel oil than from any other cause and for that reason more than usual care should be taken to insure an absolutely steady and uniform pressure of the fuel oil at all times at the burners. If such a steady pressure is provided, satisfactory atomization can be secured with a fuel oil pressure as low as 75 lb. Any pressure between 75 and 200 lb. may be used, depending upon the power requirements and the number of burners in operation. In an emergency the fuel oil pressure may be carried to 250 lb. if necessary to secure the steam required.

Factors in the Choice of a Combustion System*

Future Selection of Firing Methods Will Lie Between the Stoker, Powdered Fuel and Low Temperature Coal Distillation. By Edwin B. Ricketts†

RECENT CHANGES which have taken place in the fuel situation together with the considerable advances in fuel burning equipment have materially increased the difficulties which face the power plant engineer when he is confronted with the problem of the choice of a combustion system.

There are at present two systems of coal burning which merit the careful consideration of engineers who must make a choice today; namely—stokers and powdered coal, hand firing having been practically eliminated not on account of any considerable lack of thermal efficiency, but because our American system of universal education together with the shifting tides of immigration have largely eliminated that ideal fireman, so plentiful 20 yr. ago, the man with a strong back and a weak mind who was glad of the opportunity to fire 20 T. of coal a watch for $2 and clean the fires while he was resting himself. There is another system which has recently appeared on the horizon and while it is yet but as "a cloud the size of a man's hand" it has possibilities which argue well for its future. I refer to the gasification process with by-product recovery; and while the mechanical development of this system does not warrant its consideration for immediate use except under especially advantageous circumstances, I feel that we may with profit discuss some of its more interesting characteristics after we have finished with the two systems which are immediately available.

The problem before us is not one of selecting the thermally most efficient system but consists of selecting that system which, when operated in conjunction with the other apparatus in the plant and supplied with the fuel which will probably be available during the useful life of the plant, will produce the largest number of salable kilowatt-hours for a dollar, when investment, operating and repair costs are all considered.

Before entering upon a detailed discussion of the relative merits of the two systems under consideration, we may with profit review briefly some of the tendencies in power plant practice which will influence the selection of a combustion system. The more important of these tendencies are:

1. Ever upward trend in coal prices which increases the importance of high thermal efficiency.
2. Rapid exhaustion of our high grade coal fields, making necessary the adoption of a system which will satisfactorily handle coals of much poorer quality than many of us have been accustomed to.
3. Tendency to heat feed water by means of steam bled from the main unit, thus restricting the range or eliminating the use of economizers.

* Presented at the Stoker Manufacturers Ass'n Convention, Briar Cliff Lodge, Oct. 24, 1923.

† Assistant to Chief Operating Engineer, The New York Edison Co.

4. Trend toward higher steam pressures and higher boiler ratings both tending to increase the flue gas temperature.
5. Combination of items 3 and 4 point to the air preheater as the only means available for conserving a large part of the flue gas heat.

Comparing these two systems in detail we find:

1. Cost of plant. The most reliable estimates which I have been able to obtain indicate that powdered coal plants will cost from $1 to $5 per kw. turbine capacity more than stoker plants and while the advocates of powdered coal claim that this will be offset by the higher ratings obtainable by the use of their system, to date no evidence to substantiate this claim has come to my attention. The powdered coal system will in my opinion start with the handicap of higher fixed charges.

2. Efficiency with coal of constant quality. The best test data on both systems indicates that, given a coal well suited to the combustion system employed, there will under test conditions be a differential in favor of powdered coal of from 1½ to 3 per cent, this difference being largely accounted for by the combustible lost with the ash and cinders and in my opinion if suitable instruments for the control of combustion are provided in each case this differential will be increased in regular operation by from 1 to 1½ per cent during steaming hours. The foregoing considerations indicate an advantage for powdered coal of from 2½ to 4½ per cent.

3. The effect on efficiency and capacity of daily and hourly fluctuations in coal quality. Due to conditions in the coal market which have frequently obtained in the past and may reoccur at any time, it is often necessary to have as many at 10 varieties of coal of widely varying characteristics in the bunker supplying one group of boilers. In stoker operation, when a change in coal occurs, it is rarely possible to detect the change in the hoppers and frequently the fireman finds his firebed upset to such an extent that it requires hours of careful nursing to restore it to normal efficiency or capacity and by the time a given firebed is straightened out for one change, another shift in characteristics may take place necessitating more hours of hard work to restore the fire to a reasonably good condition. As a concrete instance of the effect of the sudden change in coal quality, I shall mention the case of a large station having the most up to date stoker equipment, in which during the 1922 strike a shift to an untried coal was suddenly necessary and before the firemen knew what had happened a large part of the station's load had to be shifted and some of the fires were so tied up with clinkers that the boilers had to be taken out of service before the clinkers could be gotten rid of. After the fireroom force had learned the characteristics of this coal, they managed to burn it without serious trouble at a somewhat reduced capacity, but it will readily be seen that had this change occurred when there was nowhere to shift the load, the results might have been disastrous.

In pulverized coal furnaces, a shift in coal characteristics undoubtedly affects both efficiency and capacity and if a change in coal, such as described above, should take place and no adjustments be made for several hours, the result might be equally as bad as with stokers, but the fact that there is only an extremely small quantity of coal in the furnace at any given time and that the effect of the change is readily seen and may be remedied by a shift of dampers, the capacity is not likely to be so seriously affected as to materially reduce the load-carrying capacity of the station. In emergencies we are willing to put up with a loss in efficiency, but a considerable reduction in capacity frequently has serious consequences.

4. Ability to maintain high efficiency and capacity with coals of widely varying quality. Probably over 95 per cent of the coals now being mined in this country can be burned with good efficiency on some form of stoker. There is unfortunately, however, no single stoker which will give good efficiency with all these coals. Here in the East a shift from 7 to 17 per cent in ash may mean a loss of 17 per cent in capacity and 12 to 13 per cent in efficiency. The effect of such a change in quality with powdered coal would affect capacity and efficiency less than half the preceding amounts.

5. Smoke and cinders. The liability to smoke is about the same with either system. In the average stoker plant, about 3 per cent of the coal burned leaves the grates to be caught either in the boiler and flues or to go up the stack. Successful means for catching stoker cinders have been extensively applied with entirely satisfactory results. In powdered coal plants, from 40 to 70 per cent of the ash goes up the chimney and so far as my information goes, to date no cinder catcher has been demonstrated which would prevent a large powdered fuel plant located in a city from being a nuisance to its neighbors. I have no doubt that a satisfactory catcher will be developed; I hope this development will be less costly in time and money than the one for stoker cinders.

6. Ash handling and disposal. Ash handling cost within the plant will be about the same for both systems provided ash is all caught. Powdered coal ash is not available as concrete aggregate and is harder to use as fill than stoker ash. These characteristics may make it more costly in some plants to dispose of powdered coal ash than that from stokers.

7. Stand by losses will probably be less than half as much with powdered coal as with stokers. A saving of half the banking losses in Waterside last year would have amounted to 28,000 T. of coal worth $200,000, or 3 per cent of the consumption of these stations.

8. Cost of labor and auxiliary power. The best estimates available indicate that from 15 to 25 per cent more labor and from 12 to 20 kw.-hr. more auxiliary power per ton will be required for powdered coal than for stokers.

9. Cost of repairs. The best information available indicates that the repair costs on the two systems will be practically the same.

10. Frequency of taking boilers out of service for repairs to combustion equipment. On account of its greater simplicity and the absence of iron parts in the furnace, we would naturally expect the powdered coal furnace to require less shut-downs than the stoker, and the service records so far available indicate that the number of outages for furnace repairs will be about half as great with powdered coal as with stokers. Data available at this time is not sufficient, however, to give a definite value to this item.

11. Fire and explosion hazard. While up to the present time there have been no serious explosions of powdered coal in central stations, there have been many explosions of a disastrous nature in industrial installations. A study of the detailed reports on such explosions so far as available data permits indicates that in nearly every case the trouble has been due either to faulty design or gross carelessness on the part of the operators; and while there is no denying that there is inherently a greater hazard in powdered coal than with stokers, this hazard will undoubtedly be reduced to a minimum by the type of installation and the character of the personnel usually found in central stations.

12. Ability to make use of preheated air. As I have stated before, the present trend of design indicates strongly that the power station of the future will make use of air preheaters and it may prove advantageous to heat this air to 400 or 500 deg. F. at high loads with the powdered coal furnace, the higher the air is heated the better it works. With stokers there is abundant evidence that they will work satisfactorily with air heated to around 200 deg. F. I know of only two cases of the use of highly heated air on stokers—one was on an experimental chain grate stoker in France where when burning a coal with a highly refractory ash no trouble was experienced with air heated to 500 deg. F. and the other is an installation of underfeed stokers under oil stills in the Middle West where with air at about the same temperature considerable increase in clinker trouble was experienced. No definite conclusions can be drawn from this data.

The foregoing considerations may be summarized as follows:

In Favor of Stokers.

1. $1.00 to $5.00 per kw. lower first cost of plant.

5. The cinder problem on stokers has been solved and while experimental work looking to the solution of this problem for powdered coal is being actively pushed with every promise of ultimate success, a definite solution is still in the future.

6. In some plants, stoker ashes can be disposed of to better advantage.

8. Stoker plants require 15 to 25 per cent less labor and 12 to 20 per cent less auxiliary power.

9. Cost of repairs equal.

11. No explosion hazard with stokers, there is a slight hazard with powdered coal.

In Favor of Powdered Coal.

2. Operating efficiency with coal of constant quality 2½ to 4½ per cent better.

3. Daily and hourly fluctuations in coal quality do not affect capacity and efficiency to as great an extent with powdered coal as with stokers.

4. Powdered coal will give reasonably good efficiency and capacity with all types of coal. If an unsuitable coal is used on a stoker it may result in losses of very considerable magnitude.

7. Saving of from 1 to 3 per cent of the total fuel is probably due to a reduction in stand by losses.

9. Cost of repairs equal.

10. Less outages for repairs to furnace equipment are indicated.

12. There is no question about the ability of powdered coal furnaces to use highly preheated air to advantage, with stokers this question is still to be determined.

Of the 12 items mentioned, stokers have the advantage in 5 and powdered coal in 6. The relative value of these factors when translated into dollars will vary with each plant. I have stated, as I see them, the arguments on both sides in the case of stokers vs. powdered coal and while I have drawn no conclusions I feel that the statement of the case which I have outlined above offers food for thought on the part of those who expect to furnish the combustion equipment of the future.

Having paid our respects to the combustion systems of the present, let us consider briefly what some may consider a pipe dream of the future. I make no claim that the idea of the system which I will outline is original. It was suggested to me by a remark which Prof. Stadola made to Mr. Orrok during his recent visit to Europe.

As I see it, the troubles with the fuel situation are largely questions of load factor and transportation, and once these questions are solved the rest of the coal problem is easy.

The scheme which I suggest for your consideration is briefly as follows:

Locate at the coal mine plants for converting the coal into gas; the exact type of apparatus to be used cannot be definitely outlined at this time but would probably consist of low temperature distillation with by-product recovery, followed by complete gasification of a part of the resultant coke in producers. The gas from both these systems would be mixed resulting in a gas having about 400 B.t.u. per cu. ft., this gas being pumped at high pressure to the center of consumption where it would supply all heating requirements both industrial and domestic. While both heating and power loads are lighter in the warm months, the valley thus created in our load curve could be evened up, making coke for domestic and industrial fuel at this time. This coke would be sold in those remote localities which could not be served from the gas lines. Coke stores well and most domestic consumers have been educated to lay in their winter supply in the summer when they can get it.

The principal advantages of this system are:

1. The miner would have work 300 days per year instead of 200 as at present and could consequently make a good living with much less labor cost per ton.

2. With 100 per cent load factor the mine overhead would be about cut in half.

3. Many coals too poor in quality to stand transportation costs could be profitably used in this way.

4. Transportation delays due to strikes, weather and railroad congestion would be largely eliminated.

5. Congestion in our city streets caused by hauling coal and ashes would be eliminated.

6. Coal by-products would take the place of our rapidly disappearing oil reserves.

7. The consumer would get a regular supply of clean fuel of a standard quality at a standard price and all the ash, slate and stone would be left back in the hill country where there is plenty of room for it.

There are few unsolved problems in this scheme and from the enormous amount of development work which is going on all over the world at the present time, I firmly believe that many of those present today will live to see this scheme completely worked out and operating on a country wide scale.

Ventilation Applied to Central Station Buildings

LOSSES ENCOUNTERED IN THE OPERATION OF ELECTRICAL MACHINERY MANIFEST THEMSELVES AS HEAT WHICH MUST BE CARRIED AWAY USUALLY BY CURRENTS OF AIR. THE PROBLEMS INVOLVED ARE BROUGHT OUT IN N. E. L. A. COMMITTEE REPORT

AS A result of its investigations of ventilation requirements and means for moving, cleaning and cooling air for electrical equipment and central station buildings, the subcommittee on ventilation of the Electrical Apparatus Committee of the National Electric Light Association has recently made its report public. Considerable data and discussion of a general nature, dealing with the employment or conditioning of masses of air, are included in the complete report. In the article which follows are given only the data and conclusions arrived at which are thought to be of greatest value to central station engineers.

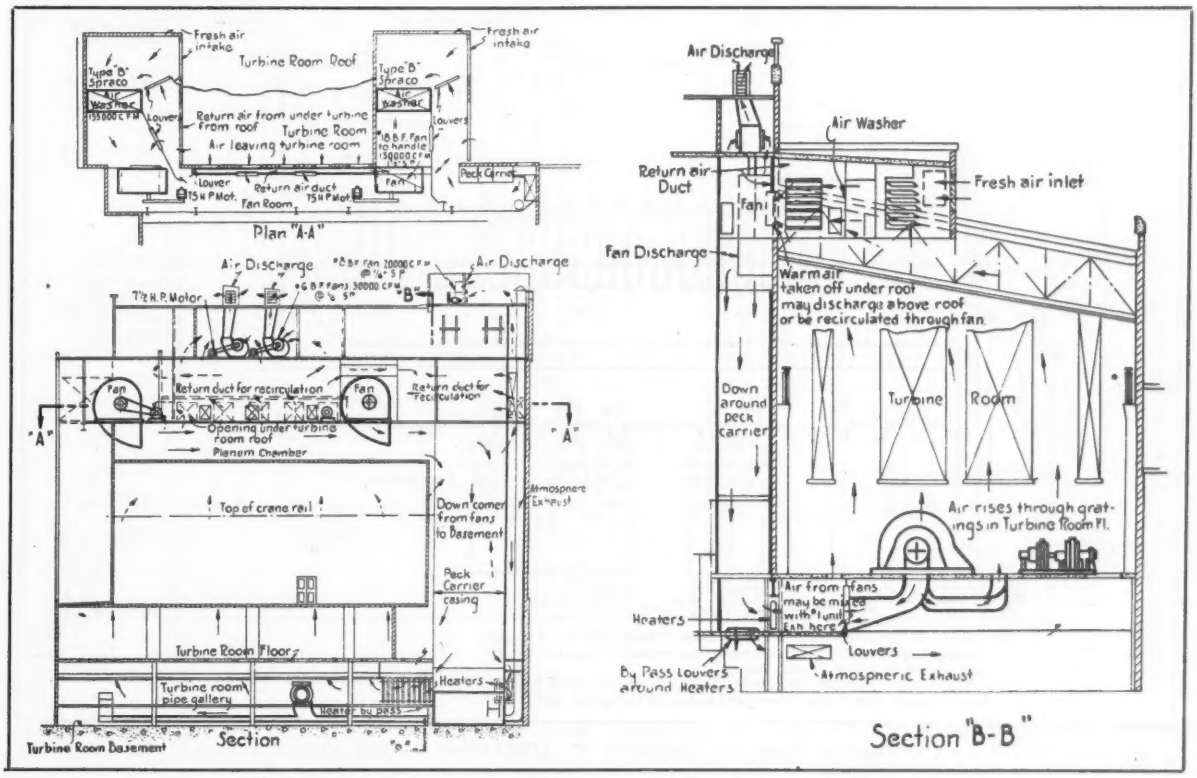


FIG. 1. VENTILATING SYSTEM OF DETROIT EDISON CO.'S MARYSVILLE PLANT

As a result of its investigations of ventilation requirements and means for moving, cleaning and cooling air for electrical equipment and central station buildings, the subcommittee on ventilation of the Electrical Apparatus Committee of the National Electric Light Association has recently made its report public. Considerable data and discussion of a general nature, dealing with the employment or conditioning of masses of air, are included in the complete report. In the article which follows are given only the data and conclusions arrived at which are thought to be of greatest value to central station engineers.

Air for Removing Heat

Ventilation of electrical apparatus, with but few exceptions, is a cooling application and as such can be divided into two classes, direct and indirect.

Direct cooling is employed with enclosed machines by forcing air through the machine so that by contact with the radiating walls of the machine heat is conducted to the air. Indirect cooling includes such applications as cooling substations or rotary rooms and is usually termed ventilation. It is indirect cooling because the machine radiates its heat to the surrounding air and the surrounding air is removed and replaced by outside air. This ventilation becomes a dilution process and the results obtained are dependent upon the degree of dilution.

Air as a cooling medium has the advantages that it is unlimited in supply and costs only for handling, large quantities can be handled for a small expenditure of power, and natural convection currents may be utilized for moving the air. Because of its low specific heat (0.2375) and weight, however, great volumes of air must be used to remove a small amount of heat; 56 cu. ft. heated through 1 deg. F. are necessary to absorb 1 B.t.u. Other disadvantages are that air supports combustion; still air is a nonconductor of heat and it carries solid matter in suspension.

In cooling electrical apparatus, the velocity of the air may run from 1000 ft. to a mile a minute. The committee has developed the following formula for practical use in designing air ducts:

$$V = 4000\sqrt{h}$$

in which v is the velocity in feet per minute and h is the velocity head measured in inches of water, the air being at a temperature of 65 deg. F. and standard conditions of barometer, density equal to 0.075.

To move air, the horsepower required is the weight times the velocity divided 33,000. If the pressure is given in inches of water, 5.2h equals the pressure per square foot and the volume equals the velocity in feet

per minute times the area of the pipe in square feet. Then the horsepower equals 0.000,157,5 times the volume times the pressure in inches of water. This, of course, is the air horsepower and for average practice a fan efficiency of 50 per cent may be considered a fair average.

Equipment Requiring Artificial Ventilation

As the size and rotative speed of electrical equipment increased, it became necessary to enclose the larger high-speed apparatus. This was occasioned by the following conditions:

Air Pressure for Generators

Ten to twelves inches of water pressure are required to force air through a turbo-generator while only 1 to 2 in. are required for synchronous converters, synchronous motors and d.c. generators. For other classes of apparatus, especially where external blowers are not used, air velocities should be kept low, not to exceed 1000 ft. In self ventilated, enclosed machines, the velocity of air in the air ducts ranges between 1000 and 1500 ft. per min. For force-ventilated machines, with separate blowers, the air velocity in the ducts may be increased to between 2000 and 3000 ft. per min.

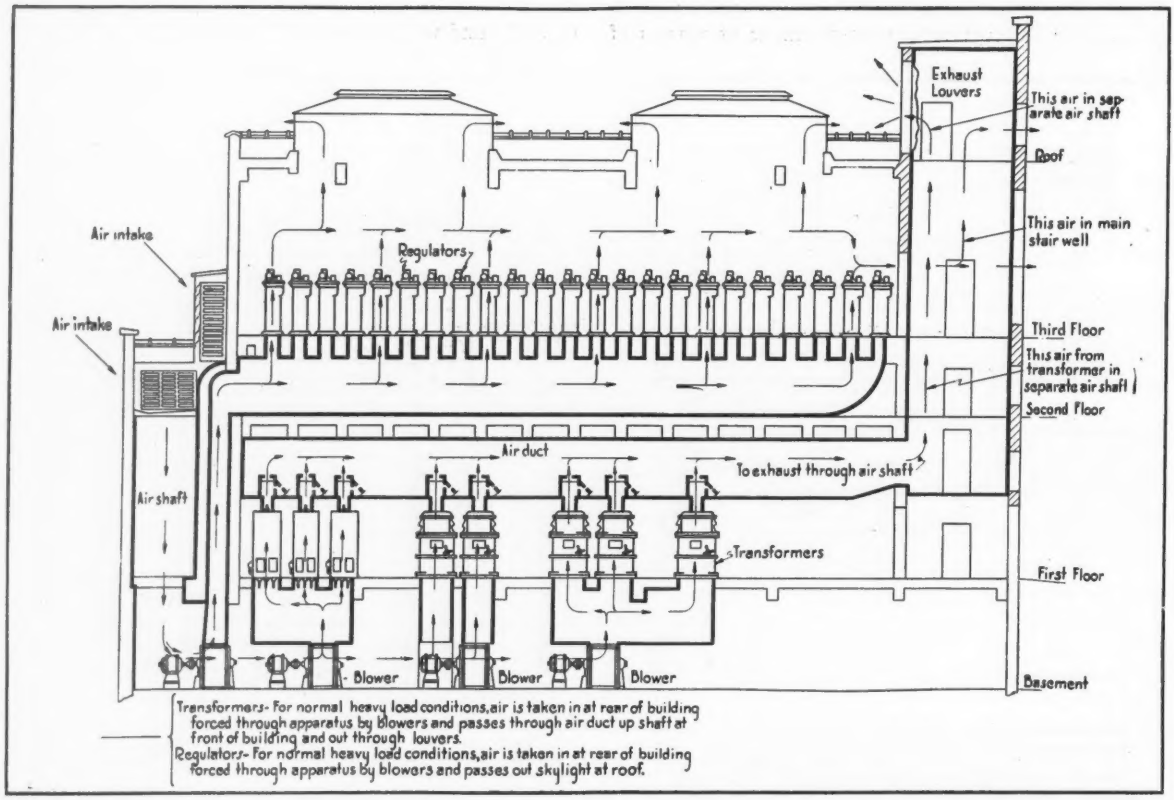

Exhaust Louvers
This air in separate air shaft
Roof
This air in main stair well
Air intake
Regulators
Air intake
Third Floor
This air from transformer in separate air shaft
Second Floor
Air duct
To exhaust through air shaft
Air shaft
Transformers
First Floor
Blower
Blower
Blower
Basement
Transformers- For normal heavy load conditions, air is taken in at rear of building forced through apparatus by blowers and passes through air duct up shaft at front of building and out through louvers.
Regulators- For normal heavy load conditions, air is taken in at rear of building forced through apparatus by blowers and passes out skylight at roof.

FIG. 2. AIR CURRENTS THROUGH ELIZABETH ST. SUBSTATION OF THE UNITED E. L. & P. CO.

1. Windage noise of high-speed machinery.
2. Need of pressure chambers in long core machines to force air through to center of core.
3. Necessity of cleaning air going to large machines.
4. Comfort of operators in stations of restricted space.
5. Obtaining cooler air from outside.
6. Avoiding possibility in motor generator sets of one machine taking hot air from the other.

From 75 to 100 cu. ft. of air per min, per kw.-hr. are required by a large machine, the lower range being used for large high-speed turbines, while the upper range is for slow-speed units. The temperature rise through the machine usually varies from 18 to 24 deg. The air for the great majority of enclosed machines is obtained and propelled through the machine by fans fastened to the rotor. The inlet and outlet ducts must be short, having few bends, of liberal radius, and of ample cross sectional area.

Turbo-generators of the horizontal type are usually enclosed with a double end bell at each end, the air being drawn from beneath into the outer bell, driven into the inner bell by fan blades at each end of the field and forced through the ventilating paths of the machine. The air outlet can be through the top into the room, through the top to the outside by a duct, or through the bottom.

Vertical generators are usually provided with a casing so that the air is drawn from beneath and enters the generator at both ends of the field, is forced through the ventilating paths in the generator and out to the room or through a duct outside the building.

Ventilating System at Marysville

At the Marysville plant of the Detroit Edison Co. the system of ventilation, based on the company's experiences at Connors Creek plant, has been designed: first to cool the generator with washed air; second, to

collect and remove water vapor escaping from the turbine; third, to prevent condensation on the turbine room ceiling; and fourth, to heat the turbine and condenser rooms in winter and cool with washed air in the summer. The arrangement of ventilating equipment and direction of air currents are shown in Fig. 1.

One of the latest schemes of air blast transformer ventilation, which is to be used in the Elizabeth Street substation of the United Electric Light & Power Co., includes exhaust ducts arranged to take air directly from the outlet of the transformer and carry it to the exhaust outlets at the roof which not only provide lower room temperatures, but are also of some relief to the operator. The arrangement is shown in Fig. 2.

In this station where the transformers were installed

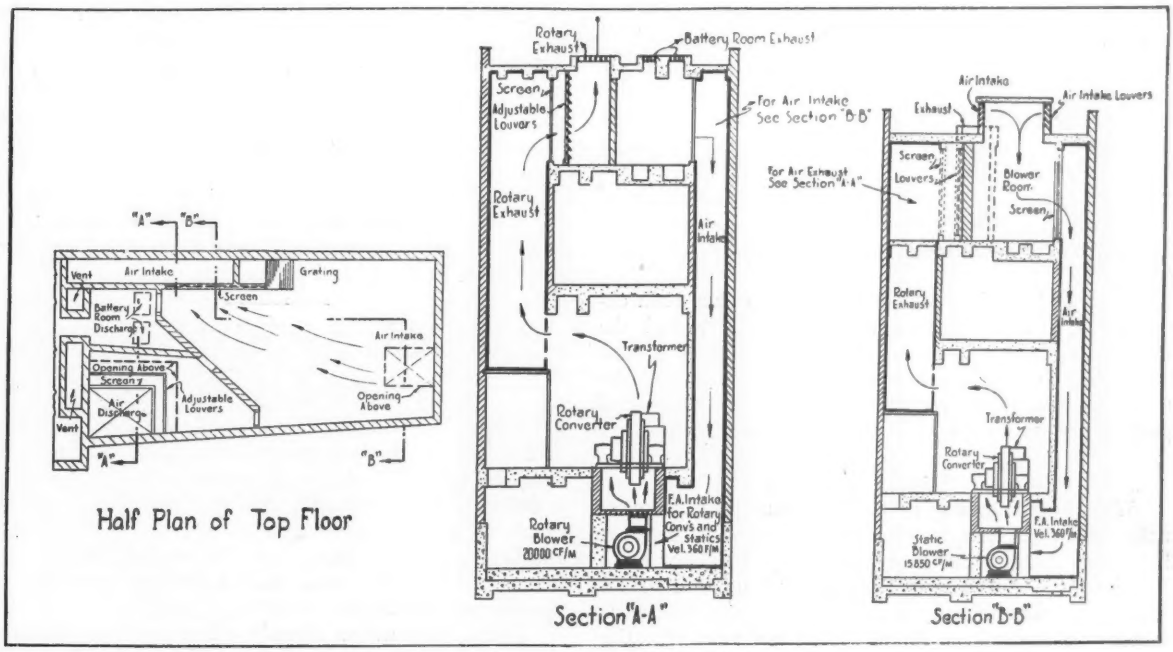


FIG. 3. PLAN AND SECTIONS OF NEW YORK EDISON CO.'S STONE ST. SUBSTATION

in vaults, the following formula for vents was worked out theoretically and then checked up by test:

$$A = P\sqrt{H} \div 2.18$$

where A equals the area of each vent in square inches, P equals losses in watts at full load of the transformers and H equals the vertical distance between centers of vents in feet. It provides for temperature of the outlet air of approximately 40 deg. C. with an intaking air temperature of 25 deg. C.

Substations Require Forced Circulation

Mechanical ventilation for substations has been found necessary, due to a number of causes, principal among which are mentioned the increasing sizes of transformers and converter units; manufacturers insistance upon compliance with specifications on air requirements; usual confinement within closed walls; concentration of larger units within a small area; and the large volumes of air required, which in a plant of five 4000-kw. converters amounts to 185,000 cu. ft. of air per min.

In selecting the point of admission for fresh air, care must be taken to avoid drawing any of the air over the sidewalk which is usually heavily laden with dust and such point must be remote from the point of discharge.

Need of Air Washers in Substations Doubtful

As to air washers for substations, the question is still being debated whether or not they will ever be required, even in stations where space provisions have been made.

On account of the high velocity of the incoming air, rain and snow are drawn in, and in extremely cold weather, snow is frequently drawn into the nearest machine. To provide against this, shutters are introduced in the air passageway which may be quickly closed, shutting off entirely or throttling the incoming air. At the bottom of the air intake a drain is provided connected directly to the sewer or a sump pit. The size of the inlet should be such that the velocity of the air would never exceed 1200 ft. per min.

Provisions for Exhaust

Heated air rising from the various machines in the substation should be picked out at various locations near the ceiling, otherwise uneven temperatures will prevail throughout the station with resultant unsatisfactory operation of some of the machines. Care must be taken in the arrangement of ducts to see that the exhaust air is not drawn directly into the intake.

In many cases, the warm air exhaust through the roof fans is discharged at points lower than the neighboring buildings and in the summer time when the windows are kept open and the air is particularly warm, great care must be used to prevent annoyance to neighbors. The exhaust must therefore be carried as nearly vertical as possible and located after carefully surveying the neighboring conditions. Good results are often obtained by exhausting through holes in the roof without the introduction of pipes or ducts projecting above the roof.

To eliminate the disagreeable noise which accompanies the exhaust of air at high velocity, the arrangement recommended is to provide a large chamber to receive the air, which in turn vents to the roof through a steel grating, the sound is hardly audible except to one standing near the grating on the roof.

Arrangement of Stone Street Substation

In the Stone Street substation of the New York Edison Co. the scheme, as will be observed in Fig. 3, is to bring the fresh air in from the roof through a vertical shaft at a velocity of 900 ft. per min. to a chamber under the rotary converters and the air blast transformers, entering the chamber directly at the middle point, and in this chamber are located the blowers discharging directly upward into the converters and transformers. The capacity of the converter is 4200 kw., and of its blower, 20,000 cu. ft. per min. at 1 in. static pressure.

Ventilation of a storage battery room is similar in many respects to the general ventilation of the rotary room or any other large room. The question of the number of air changes per hour must be determined by experience after observing the effects of a rapid charging or discharging of the battery. The principal problem in the ventilation of the battery room is to destroy the acid fumes before they are discharged into the atmosphere.

As to acid eliminators, the best results have been obtained by a spray washer with fresh water and the standard form of eliminator plates. The acid eliminator must be introduced between the battery room and the fan. To prevent corrosion of the fan, an acid proof paint or, better still, a lead wash is recommended.

Elimination of Noise

While considerable is heard about prevention of noises in substations, no great amount of work seems to have been done along these lines except in a few cases. For instance, it is almost universally true that in stations not fundamentally designed to be noiseless, satisfactory relief has been found by enclosing the offending piece of machinery in a separate room and discharging its air through the roof. Likewise, improved methods of machine ventilation such as ducts and partitions seem to help materially.

Radiator Type Coolers Growing in Favor

Recent interest has been shown in the question of the use of radiator type coolers for removing the heat from the ventilating air in electric machinery.

The radiator type of cooler lends itself to the use of the closed air system of cooling. The hot air is taken from the machine, passed through the cooler, and sent back again to the machine. Such a system eliminates the possibility of carrying large volumes of dirt into the machine as now occurs with the open type cooling system.

When a washer is employed, the present open type system removes the major part of the dirt, nevertheless, with the enormous volumes of air, some dirt passes the washer. The closed system also eliminates, to a large extent, the possibility of moisture being carried into the generator. The closed system shortens up the air ducts and simplifies the station layout. There is also some advantage in the elimination of fire hazard, as the burning of insulation, if started, is choked down, due to the exhaustion of the oxygen in the closed circuit. The station noise will, in general, be reduced, as there is no direct communication between the air from the alternator and the outside air. When salt water is the only medium available for cooling a wet filter is not possible, but a surface cooler can be used.

The factors involved in the design of the surface cooler are: the losses to be handled; volume of air; the value of the temperature rise of the air leaving the cooler; temperature of the cooling water; and the permissible pressure drop through the cooler for the air circuit.

In this country, commercial air washers, such as used for washing and cooling the air supply for ventilating electrical apparatus, are almost entirely of the spray type. Rotating metal or fixed cloth screens, coke washers and other wet filters are not commonly used in this country, but are quite generally used in Europe.

Reduction in temperature of air by evaporation of the spray water provides a maximum air temperature for cooling and ventilating a generator seldom exceeding 75 deg. F. The air velocity through the spray chamber is usually confined to 500 to 700 ft. per min. and at such velocities the resistance to the flow of air or the pressure drop will be from ¼ to ½ in. water gage. The amount of water sprayed will vary from 4 to 8 gal. per 1000 cu. ft. of air washed per minute.

Standards for High Pressure Flanges Are Planned

WORK has been actively started on a comprehensive program of standardization of steel flanges and flanged fitting for steam pressures ranging from 250 to 3200 lb. The three sponsors for this work are: Committee of Manufacturers on Standardization of Fittings and Valves, the Heating and Piping Contractors National Association, and the American Society of Mechanical Engineers.

Preliminary action already taken provides that the maximum steam pressures for which these standards shall be developed are 250, 400, 600, 900, 1350, 2000, and 3200 lb. per sq. in. The maximum temperature which they will be designed to withstand has been set at 750 deg. F. Steel standards for steam pressures of 250 and 400 lb. are to have the same bolt circle and number of bolts as the present American cast-iron standard for 250 lb. except that the 2 and 2½-in. sizes for 400 lb. pressure shall have eight bolts instead of four. Other flange dimensions are to be modified to meet the condition set for each.

It has further been decided that for 600 lb. steam pressure the basis of dimensions shall be the bolt circle and number of bolts of the present 800 lb. hydraulic standard developed in 1918 by the A. S. M. E. committee.

The 900-lb. steam standard will have as its basis the bolt circle and number of bolts of the present 1200 lb. hydraulic standard developed by the A. S. M. E. committee and published December, 1918.

Standards for 1350, 2000, and 3200 lb. steam pressure are to be developed after the completion of the first four of the series. Dimensional standardization will be started as soon as the chemical and physical properties of the materials have been decided upon.

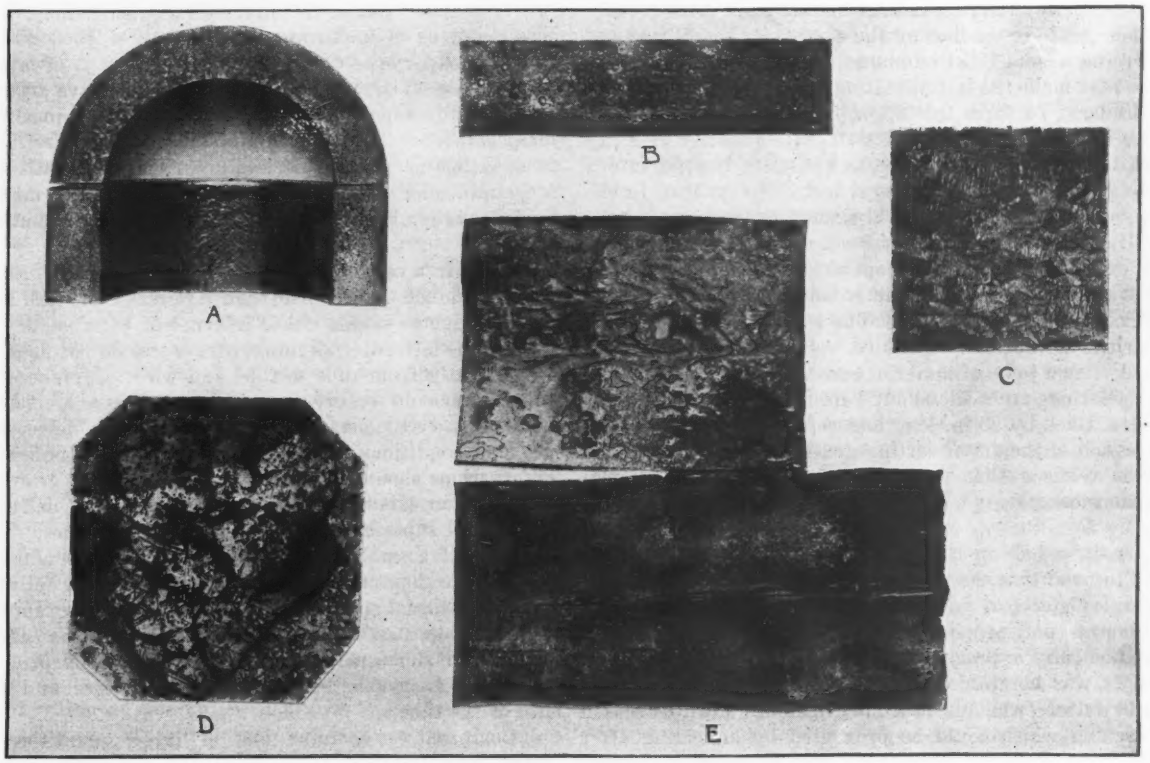
Factors Affecting Condenser Tube Failures

CHOICE OF MATERIAL AND MANUFACTURING PROCESSES ARE PRINCIPAL CONSIDERATIONS IN COMBATING SEASON CRACKING AND CORROSION. BY WILLIAM R. WEBSTER*

FEW problems relating to the operation of steam power plants, both marine and stationary, involve greater perplexities than those surrounding the endurance of the tubes employed in surface condensers where salt or contaminated cooling water is used.

Failures experienced are of two kinds. One is due to spontaneous longitudinal splitting of the tube which is an exhibition of the phenomenon known as season cracking. The other is caused by the corrosive attack of the cooling water or of substances carried by it. In point of frequency of occurrence, the former is now of relatively minor importance, but because of the fact that when it is encountered it involves sudden and extensive leakage, its immediate results may be of greater consequence than failure due to corrosion.

Both tube makers and tube users have, since the matter became important, given much consideration to the problem of providing and securing tubes which would give maximum length of service, but due to the erratic nature of corrosive attack and the large element of time involved, it cannot be said that sufficient facts have been established on a basis of scientific procedure to make it at this time possible for anyone within certain broad limits to predict with certainty that any particular lot of tubes will endure under average service conditions in a measurably superior degree to some other tubes differing from them in material respects. Since the matter is one of great importance in the conduct of power installation, careful study of the problem in all of its aspects is well warranted in the interest of good engineering practice.



APPEARANCE OF VARIOUS CONDITIONS OF CONDENSER-TUBE MATERIAL

A. Longitudinal and cross sections of an acceptable shell casting. B. A common form of dezincification: formation of plugs of spongy copper due to removal of zinc in spots—looking into a section of tube cut open longitudinally. C. Structure of tube which gave an extraordinary life. D. Copper plug, magnified. E. Two sections of a tube, cut longitudinally and spread open: the short section shows perforations due to entrained air corrosion; the larger portion, though free from attack, has a large spill.

COMPOSITION OF TUBE METAL

Originally most condenser tubes were made of a mixture of about 70 per cent of copper and 30 per cent of zinc, this composition being dictated by considerations affecting the manufacture rather than the performance of the tubes. Experience having demonstrated that the presence of a small amount of tin retarded the corrosive effects of sea water, some experiments were made in which 1 per cent of tin was substituted for 1 per cent of zinc, with the result that superior resistance to corrosion was obtained. This specification was originally adopted by the British Admiralty, since which time the term "Admiralty mixture" or metal has been employed to designate it.

*Vice-president of the Bridgeport Brass Co. An abstract of a paper presented, Nov. 8, before the Metropolitan Section of the A. S. M. E.

It was stated above that season cracking was a recognizable cause of tube failure. For this a complete and sufficient remedy is a modern degree of annealing. It was originally the practice to furnish condenser tubes hard, i. e., without any final heat treatment. No way is known to the art by which tubes so made can be positively assured against this trouble. On the writer's recommendation, the Bureau of Steam Engineering of the Navy Department somewhat over 20 yr. ago adopted specifications requiring that tubes be annealed after the final drawing operation. This practice has since become standard in this country although English manufacturers still continue to omit a final annealing.

Admiralty mixture is hot short and can consequently not be made into tubes by the customary method of hot piercing a solid billet or blank. Instead the usual practice is to make the initial casting in the shape of a hollow cylinder. To form this appropriate amount of copper, zinc and tin, together with a suitable quantity of scrap are brought to a molten state and then poured into a vertically disposed cylindrical mold of cast iron in the center of which a cylindrical sand core is supported.

Lead and iron are considered deleterious impurities. In excess both hamper the operations of the tube maker, and the latter in particular is believed to assist the attack of corrosive agencies. The effect of such other impurities as normally exist in well made brass has not been shown to be of material consequence.

Castings are made about 4 in. in outside diameter by ⅝ in. thick by 50 in. long and represent the highest expression of the art of casting non-ferrous metals. When it is realized that a casting of the above mentioned dimensions having a cross-sectional area of about 7 sq. in. is by a succession of cold drawing operations, reduced to a tube having a cross-sectional area of about 0.15 sq. in., and that the resulting product must be free from visible defects of any character, the perfection of both structure and properties which must be possessed by it will be fully appreciated.

It was heretofore stated that one of the causes of tube failure was due to a phenomenon known as season cracking which could be prevented by annealing after the final drawing operation. By properly governing the drawing operations the tendency to season crack can be controlled to some degree, but it cannot by this means alone be eliminated with certainty.

Since a condenser tube when fully annealed is so soft as to be readily distorted by treatment incident to handling and installation, it is customary practice to modify the final anneal to a degree that will, while removing all liability to season cracking, still leave the tube hard enough to withstand handling.

For determining whether the annealing operation has been so conducted as to prevent season cracking on the one hand and undue pliability on the other, the metallurgical microscope is an extremely useful instrument, but its value as a means of predicting service endurance has not been established by any well attested record of experience.

Interesting, however, as the methods employed in making condenser tubes may be to the power engineer the subject of tube failures is more so. It will be at once evident that failure due to season cracking is readily and completely avoidable, since the degree of annealing necessary to prevent it is well below the point at which the metal becomes unduly soft. In order to guard against this latter possibility it has sometimes been thought necessary to require that a unit length of the tube be capable of sustaining a specific load applied perpendicularly to its axis without taking a permanent set exceeding a certain amount. As the size of the crystals of the tube can be determined microscopically with a fair degree of approximation and since this size is proportionate to the softness of the tube, this requirement is unnecessary in the presence of a definite limit for the crystal or grain size. In this connection, however, it is desired to call attention to the fact that the factor of observational error involved in the measurement of crystal size is large.

While perfection of manufacturing practice may well be stressed as of importance in the way of good workmanship, experience does not indicate that it is of much consequence on the whole in preventing corrosive attack. The belief is widely held that the control of annealing temperature within close limits and extreme freedom from visible mechanical defects are essential to satisfactory endurance. In the former case, fortunately, ample evidence is available and merely lacks sufficient examination.

Tubes in a condenser usually fail in succession, some giving a much longer life than others. Such failures must be due to causes either internal or external to the tubes. The latter in individual condensers do not usually vary greatly from tube to tube and when differences in this respect do occur, they can usually be detected. Under those circumstances, when variations in detectable internal conditions exist a sufficiently large number of observations should be able to determine with certainty any relation existing between any specific internal condition and superior or inferior service endurance. For example, if a small crystal structure is more conducive to long life than one relatively large, the earlier failures in an individual condenser will be found upon examination to possess, on the average, larger crystals than those which fail subsequently, with some degree of proportionality observable between the crystal size and the life of the tube.

Comparative examinations of large quantities of failed and unfailed tubes from the same condensers, while always showing variations in crystal size of considerable amounts, have not given the slightest support to this belief. Similarly, attempts to explain observed failures by the presence of mechanical imperfections have been unfruitful. Dr. G. D. Bengough, in discussing this factor, has stated that "in my experience it is very rare for tubes to fail from this cause."

Should, however, the facts above mentioned be admitted by all, that alone would contribute but little to the solution of the problem of condenser tube failure. On the other hand, if such admission should serve to direct attention to the importance and necessity of more intensive study of the causes of corrosion which reside within the condenser, much would have been accomplished in the direction of substantial progress.

Tube Corrosion

To discuss the precise mechanism of the corrosive attack involved in the failure of condenser tubes is beyond the scope of this paper. Suffice it to say, therefore, that the corrosive agencies existing in the average surface condenser using sea water are sufficiently active to make the destruction of any brass tube only a ques-

tion of time, and that the reason why brass tubes last on the whole as well as they do is that corrosive action is usually accompanied by the formation of by-products which are distinctly protective.

Specifically, if a piece of condenser tube be immersed in warm salt water containing air bubbles, corrosive attack will continue for a considerable period at a rate sufficient completely to dissolve it in a few months. Also corrosive attack of a character not involving the formation of a protective coating may occur under perfectly normal conditions and proceed at a rate sufficiently rapid to perforate the tube in a few weeks.

Investigations of the subject of condenser tube corrosion have established the existence of a considerable number of distinctive types of attack, a comprehensive discussion of which would require a paper by itself. Some of the commoner types, however, demand attention. Probably the most troublesome is that usually known as "plug type dezincification," wherein approximately circular areas of the tube wall of small size are so attacked that the zinc appears to have been dissolved out leaving a spongy mass or plug of copper behind. This action once set up continues at a rapid rate until the wall of the tube is perforated. The spongy copper is not strongly adherent and frequently falls or is washed out of place leaving an approximately circular hole. This type of corrosion is the one which usually accounts for the rapid failure of new tubes. Perforations from this cause may take place within a few months or even weeks from the time the tubes are installed.

Chemical reactions involved are complex but appear to be favored by a high degree of salinity. Frequently the attack occurs along the bottom element of the tube under conditions indicating that when drained, water has collected in the bottom and that concentration due to evaporation has occurred. Attempts to produce this action experimentally have not been entirely conclusive. A slight inclination to the condenser so that the tubes will drain dry and the avoidance of sagging appear to have value as preventive measures and should always be adopted. Frequent thorough cleaning of the tubes when new is also desirable, particularly if the condenser is out of service for extended periods.

Under certain circumstances a type of corrosion resembling this is encountered which differs from it in that the action instead of being localized occurs quite regularly throughout the entire wall of the tube and proceeds at a much lower rate until the whole tube becomes brittle and lacking in strength. This is observed usually only in installations that have been in operation for many years although Muntz metal tubes generally fail in sea water from this cause in a relatively short time.

Quite frequently failures occur from an action as a result of which the wall of the tube is dissolved in an irregular manner sometimes involving extensive areas and sometimes quite restricted ones. Continuous action of this character usually reduces the thickness of the tube particularly at and near the inlet end so that the packing functions although it frequently localizes in a way that produces perforation without much thinning of the adjacent portions. Dr. Bengough has investigated this type of failure and proved conclusively that it is due to the presence of entrained air in the condensing water. This may be due to various causes such as improper design of circulating pumps, leaks in the suction line or disturbances in the vicinity of the intake. He recommends soaking the tubes in quiescent sea water at 40 deg. C. for about a week. This appears to form a protective coating.

In general, tubes should be cleaned as frequently as possible particularly when first installed. Deposits of foreign matter, especially when foul water is used, are frequently of a highly corrosive nature. In the writer's experience, iron protective plates properly attached to the tube sheets have a distinct value and should always be employed. The omission of the final pickling operation so as not to disturb the oxide scale formed in the final anneal has been recommended by distinguished authority. Experimental observations indicate that it is well worthy of extended trial.

Tubes for Fresh Water

This discussion heretofore has concerned itself only with tubes of Admiralty mixture as their use is indicated in most cases where corrosive action is to be expected. In installations employing uncontaminated fresh water, Muntz metal gives satisfactory results. This mixture, which is approximately 60 per cent copper and 40 per cent zinc, is inherently cheaper than Admiralty and the process of manufacture less costly due to the fact that it is capable of being worked hot.

Engineers in the endeavor to avoid the serious difficulties incident to the premature failure of tubes in service have exhibited considerable ingenuity and industry in drawing exacting and conflicting specifications. It can, however, be confidently stated that no facts whatever supported by any records of experience exist by which the observable or measurable properties of a condenser tube beyond those incident to good workmanship can be predictably related to its service endurance. The effect of such specifications, therefore, can only be to increase the ultimate cost of condensation. The American Society for Testing Materials has adopted specifications which it is believed comprehensively cover all the requirements of the best manufacturing practice and their unanimous acceptance by both producers and consumers alike could have no other result than to bestow on the industry all of the benefits incident to the introduction of standards into a situation in which they have had no previous existence.

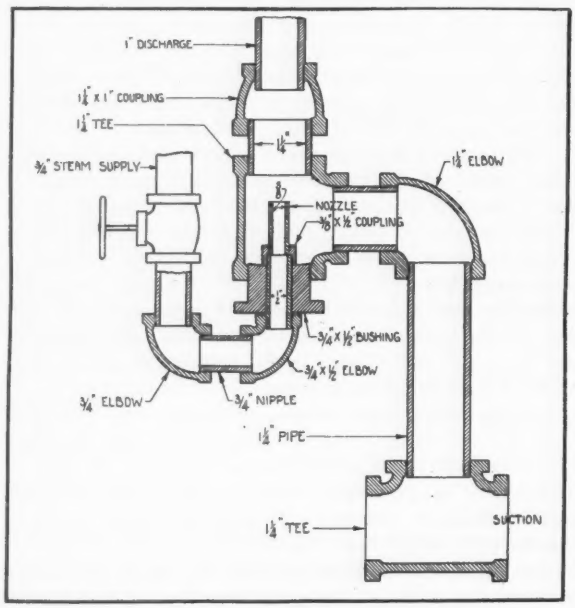
In conclusion, the writer wishes to point out the desirability of and necessity for a thorough investigation of condensers and the conditions under which they are operated as a means of providing data looking to the solution of the problem of tube failure. If in the presence of adequate records of temperature, water velocities, shutdowns, cleaning procedure, etc., failed tubes are withdrawn as they give out and the character of corrosive action involved in each case determined, much more progress will be made than through any amount of speculation based upon the physical and other properties of the tubes themselves.

To burn 25 lb. of pea coal per square foot of grate surface per hour requires a stack 175 ft. high. A stack 390 ft. high would be required to burn the same amount of No. 3 buckwheat. This shows that when the small sizes of anthracite are to be burned mechanical draft must be utilized because the stack height for natural draft becomes prohibitive.

LETTERS DIRECT FROM THE PLANT

Ejector Made from Pipe Fittings

To ONE engaged in the operation of a portable plant, a general utility ejector is a desirable piece of apparatus to have at hand. The uses to which it may be put are many and varied. Its ability to handle liquids may be utilized for almost any purpose from pumping out inundated areas in excavation work to supplying feed water for the boiler. Where funds are not available



SECTION THROUGH STEAM EJECTOR MADE UP OF STANDARD PIPE FITTINGS

for a standard piece of equipment, one may readily be made up from pipe fittings. Such an ejector is shown in the accompanying sketch. The length dimensions in general need not necessarily correspond with those indicated, but may be altered to suit individual requirements. This does not apply, however, to the short length of pipe forming the steam nozzle. For best results, the end of this pipe, in the mixing chamber (the 1¼-in. tee), should have a definitely fixed position in relation to the suction inlet. In this case, the end of the nozzle should be just above the center line of the suction opening. For larger sizes, this point becomes of increasing importance. If it is not just right, the action of the ejector is likely to be intermittent, spurting first water, then steam. In some cases, the steam may even blow back through the suction line.

Medford, Mass. A. L. ALEXANDER.

Pulling Power of Slack Belts

THERE HAS always been some question in the minds of many belt users regarding the pulling power of slack belts. Many think that a slack belt cannot pull as heavy a load as can a tight belt.

Out of curiosity, therefore, and for the purpose of setting at rest the minds of those who might be opposed to slack belts, I have checked over data on a number of actual slack belt drives and am giving the results in the table below covering all of the slack belts on which figures were procurable, namely, 11 leather belts, 2 gandy belts and 3 cotton belts.

I will admit that I was amazed to find in one instance that with a gandy belt the pull per inch of width runs up to 264 lb. For a leather belt the highest pull per inch of width is 117 lb. and for a cotton belt 127 lb. This, of course, does not mean that the ratios of pulling power of these respective belts are 264, 117, and 127. I believe that these "happened" to be the loads and that they could be interchanged if necessary without difficulty. I have much faith in the slack belt when operated under proper conditions. One of the leather belts, as will be noticed, is a laminated belt.

POWER TRANSMITTED BY SLACK BELTS

Width, inches	Thickness	Belt Speed ft. per min.	Total Pull, lb.	Pull per In. of Width, lb.	Total Hp.	Power allowed with tight belt
		Leather				
20	3-ply	1410	2340	117	100	70.5
14	....	2090	1580	113	100	....
14	2-ply	4330	952	68	125	121
19	2-ply	1412	2100	110	90	54
6	2-ply	1200	688	114	25	14.4
14	2-ply	1140	1010	72.3	35	32
8	Single	1350	489	61.2	20	13.5
12	Laminated	2500	1110	92.6	82	....
16	2-ply	3060	1078	67.5	100	98
		Gandy				
16	....	2340	4230	264	300	....
12	....	2770	438	36.5	50	....
		Cotton				
12	6-ply	3360	735	61.2	75	....
10	....	1810	1275	127	70	....
10	....	3110	900	90	85	....

Rules that are used most by belting manufacturers as applied to tight belts are as follows:

*All rights reserved by the author.

"A single belt, running 800 ft. per min., will transmit one hp. per in. of width.

"A double belt, running 500 ft. per min., will transmit one hp. per in. of width.

"A three-ply belt, running 400 ft. per min., will transmit one hp. per in. of width.

"A four-ply belt, running 300 ft. per min., will transmit one hp. per in. of width."

W. F. SCHAPHORST.

Painting Boiler Prevents Corrosion

THE ARTICLE, "Painting Boiler Prevents Corrosion," by James E. Noble in the Oct. 15 number, parallels in part an experience of the writer in a power plant in one of the southern states. Boiler corrosion was exceptionally rapid, being due to the water supply, which came from freestone springs, and which was freer of impurities than is rainwater in many localities.

Trouble manifested itself in a belt at the normal water line, ranging from about 8 in. above the level to perhaps 14 below. In this strip, corrosion was so rapid that one out of the five boilers in the battery would be out of commission most of the time. When chemical remedies failed, paint was suggested and a number of strips of boiler plate were covered with various paints and hung within a boiler to test their relative efficacies. The results, the best being ranked first, follow:

1. Boiled oil and zinc oxide.
2. Boiled oil and lead oxide.
3. Asphalt (high melting point) and Portland cement.
4. Boiled oil and Portland cement.
5. Boiled oil and iron oxide (red).
6. Commercial corrosion-resistant paints.

Oil and zinc oxide compounds were selected. The boiler to be treated was sand blasted to remove any traces of rust, and the painting was done with an air brush, one coat being allowed to dry for two days before being followed with a second.

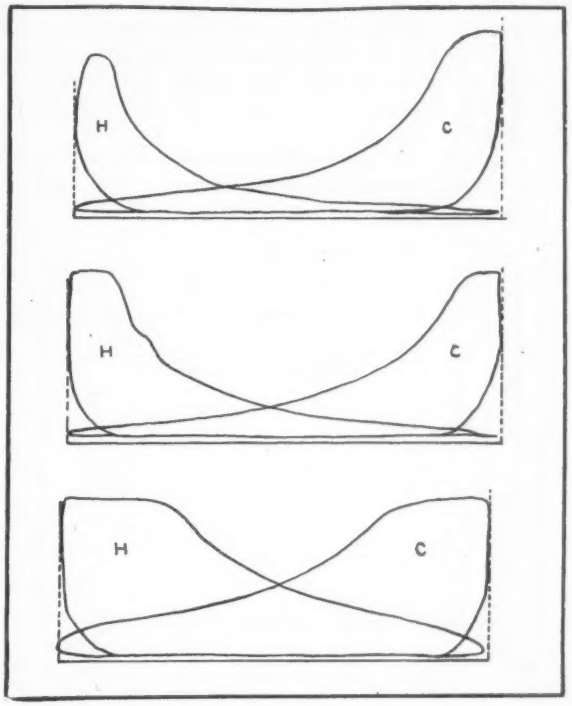
Periodic painting practically eliminated corrosion; but the job was such a trying one that, when opportunity offered, the Schoop metal spraying process was tried, using zinc as the cover metal. This metal, when applied over a sand-blasted surface, developed no expansion difficulties over the evaporation temperature range, and did not, as was feared, set up local electric currents within the boiler and thus encourage pitting at the edge of the protecting belt. Boiler shells which were so "armor-plated" prior to 1917 were at last reports still in service, with no evidence of the former devastating corrosion.

Trenton, N. J. CHESTER LYNNDELLE.

Engine Valve Adjustment

IN THE course of a general inspection recently, an indicator was applied to our direct connected Corliss type engine running at 150 r.p.m., and diagram No. 1 was taken, on a light load. An analysis of the card showed that the crank end of the cylinder was doing most of the work. The head end steam valve was slow in operating and as a consequence the maximum pressure in the head end did not approach that obtained in the crank end. The steam wristplate travel was found to be unequal. This was adjusted first by shortening the valve rod a trifle which resulted in giving the head end earlier, and the crank end later opening. As the crank end admission was normal before this adjustment, it was now late. To overcome this difficulty the eccentric was advanced somewhat. The result was as shown in diagram No. 2.

This card shows unequal cutoff with the head end taking the larger share of the load. The governor rods were adjusted to take care of this inequality and card No. 3 was taken with an increased load. Other cards than those shown were taken, of course, but these were



SERIES OF INDICATOR DIAGRAMS FROM A CORLISS TYPE ENGINE TAKEN DURING THE COURSE OF SOME VALVE ADJUSTMENTS

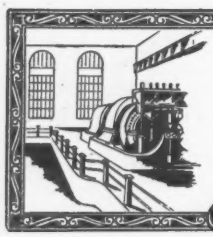
picked out as best representing the changes that were made.

TOM JONES.

Wet Sawdust for Oil or Gasoline Fires

WATER IS not effective in fighting oil or gasoline fires, as the water tends to get under these lighter oils and spread them. Sand is more effective. Wet sand is better than the dry, but only a small amount of water can be retained by sand. A more satisfactory means of combating oil fires, other than chemical extinguishers, is with saturated sawdust. One might assume that sawdust, dry, would simply feed the flame, but the reverse is true; dry sawdust will smother the flame by cutting off the air. Sawdust smothers the flame, the water cools the gases and the combination serves to quench the fire. Fill the fire buckets with sawdust and water, adjacent to the oil supplies or wherever large quantities of oil are used and you have at hand an efficient means of combating the fire in the event one should start.

Washington, D. C. G. A. LUERS.



PROBLEMS IN OPERATING POWER EQUIPMENT

Change in Ammonia Suction Piping

THE ACCOMPANYING sketch is that of the ammonia suction lines of the refrigerating system as I find them in the plant I am now operating. We contemplate changing this arrangement and I should like some suggestions as to what method of tying in the system will give the best results.

I should like, if possible, so to arrange the piping that we can operate either compressor on either the

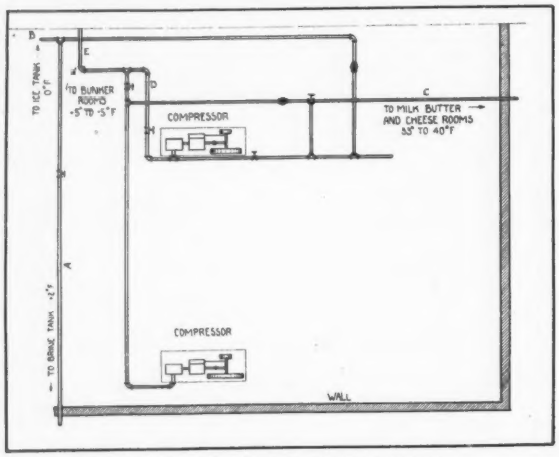


DIAGRAM OF PRESENT SUCTION PIPING

entire or part load. It seems advisable to operate the 35-T. machine on the brine, ice, and bunker rooms; and the 20-T. machine on the higher temperature rooms, during the summer months.

There will be times, of course, when we shall have to get along for a while with one machine.

What I want is to get this system to function as efficiently as possible with absolutely continuous operation during the warm months.

We want to pull one-half our ice tanks every 24 hr. Can we do it with raw water at 60 deg. F.? Will it pay us to precool our water by direct expansion before filling the cans? B. M.

Oil in the Feed Heater; Cylinder Lubrication

IN OUR plant we are using a closed feed water heater in which we find, when we clean it, about once every three months, a considerable accumulation of oil on the outside of the tubes. We have looked in vain so far for the source of this oil and would like to have your ideas as to the cause of this accumulation.

Our main exhaust is from a two cylinder 20 by 48-in. non-condensing Corliss engine. In the exhaust line, ahead of the heater we have an oil separator. Recently we looked into this separator and the trap draining it and found everything in good working condition.

We take our feed from a return tank located beneath the floor and feed it under boiler pressure through the heater into the boiler. Careful examination of the water in the returns tanks shows not a trace of oil. Even if the exhaust carried oil it could not get through the heater tubes to the shell. If the oil was carried through the heating system and returned with the condensate, I would think it would be detectable in the feed tanks. Where does the oil come from?

2. What would be considered the correct amount of lubrication (drop per minute) for the cylinder of a 20 by 48-in. Corliss engine running about 85 r.p.m. and using steam at 125 lb. carrying considerable moisture?

We are using sight feed lubricators on each cylinder as well as a force pump feeding to both cylinders.

3. In what way could the ingredients of two different cylinder oils cause them to behave differently in feeding through a lubricator? In one case, the drops of oil can be clearly seen and the glass remains clean; in another, it is impossible to keep the glass clean and the feed seems to clog up. F. G. F.

Repair of a Paper Pulley

I HAVE an 8-in. diameter by 10-in. face pressed paper pulley on a 30-hp. motor that drives our ammonia compressor. The recent use of an 8-in. belt has worn a ridge on the motor side of the pulley as it has a tendency to ride on the outer end. In one or two places the pulley looks as if a piece had been burnt or dug out and the surface as a whole is quite rough. What is the best method of replacing the pulley? A. E. T.

A. Unless this pulley is or has been water soaked to such an extent that the laminations have become separated, it is perfectly feasible to resurface it. Compressed paper of this character may be cut much like wood and may be put in a wood turning lathe and turned down with ordinary wood working tools. By turning down the face in this way, the diameter is, of course, reduced and if used in this condition the speed of the compressor will be reduced by an amount proportional to the reduction in diameter. If such a speed reduction is permissible (it will probably amount to about 6 per cent), all well and good, otherwise it will be necessary to build up the face to its original diameter. This may be done by tacking and cementing a strip of 10 in. belting (about 24 in. long) on the face. In turning down the pulley it would be well to give it a slight crown which would make the belt tend to run over the center.

While this repair is being effected, it would be well to look into the cause of the trouble to insure against its being repeated. Check up the alinement of the two pulleys, the one on the motor and the one on the compressor.

See that the shafts are parallel and the center of the pulleys in line. Any deviation from the correct condition here will work unnecessary hardships on the whole power transmission system.

Size of Boiler Feed Pump

WHAT SIZE duplex or single pump would I need for a battery of boilers rated at 500 hp. (total)? How is the size determined? C. M.

A. For boiler feed purposes, pumps are ordinarily supplied in sizes capable of handling twice the normal water demand of the boiler. If, then, your boilers are expected to be operated at rating the pump should be able to supply water for 1000 boiler horsepower. As one boiler horsepower is equivalent to the evaporation of 34.5 lb. of water from and at 212 deg. F. per hr., the pump should be able to supply $1000 \times 34.5 = 34{,}500$ lb. per hr., or 550 cu. ft. per hr. Allowing 20 per cent for slip, the volumetric displacement of the pump should be $550 \div 0.80 = 690$ cu. ft. per hr., or 11.5 cu. ft. per min.

The volumetric displacement of any reciprocating unit is obviously the total volume swept by the piston times the number of strokes per minute. The volume of the cylinder is $0.7854\ D^2L$ and the displacement per minute, $0.7854\ D^2LN$, where D is the diameter of the cylinder, L, the length, and N, the single stroke per minute. The product LN is then the piston speed which may be taken as 100 ft. per min. Equating the two expressions for displacement we have

$$0.7854\ D^2LN = 11.5$$

from which

$$D^2 = 11.5 \div 0.7854 \div LN = 14.65 \div 100 = 0.1465$$

and

$$D = \sqrt{0.1465} = 0.383 \text{ ft.} = 4.6 \text{ in.}$$

A pump of this size would probably make about 120 single strokes per minute, hence

$$L = LN \div N = 100 \div 120 = 0.833 \text{ ft.} = 10 \text{ in.}$$

For a duplex pump, the displacement per cylinder would be half of that of a simplex pump, hence

$$0.7854\ D^2LN = 5.75$$

from which

$$D^2 = 5.75 \div 0.7854 \div 100 = 0.0732$$

and

$$D = \sqrt{0.0732} = 0.271 \text{ ft.} = 3.25 \text{ in.}$$

For this size duplex pump a speed of 200 strokes per min. may be allowed, hence

$$L = 100 \div 200 = 0.5 \text{ ft.} = 6 \text{ in.}$$

Power Consumption and Speed

WE HAVE in our tool shop an emery wheel driven from a small electric motor. Both shafts are provided with 2-in. pulleys and both run at 1200 r.p.m. Would more power be required to run the wheel at 2400 r.p.m. by using a 4-in. pulley on the motor shaft? T. J. B.

A. As long as the amount of metal removed by the wheel in a given time (per minute) remains constant, the power consumption will remain practically constant, regardless of the speed. The friction losses are practically independent of the speed and the windage losses, while they increase with the speed are small and of no great consequence. To keep the rate of cutting constant, the pressure of the work on the wheel should vary inversely as the speed. If this pressure is kept constant the power requirements of the wheel will vary directly as the speed.

Safe Engine Speed

I AM operating a small slide valve engine at 300 r.p.m. It has a bore of 12 in. and a stroke of 12 in. and is equipped with a cast-iron flywheel 6 ft. in diameter. Is it safe to run the engine at this speed? J. B.

A. Inasmuch as the stroke is 1 ft. and the rotative speed 300 r.p.m., the piston speed is $2 \times 1 \times 300 = 600$ ft. per min., which is ordinarily considered conservative for this type of engine. The 6-ft. wheel turning at 300 r.p.m. would have a rim speed of $6 \times 3.14 \times 300 = 5652$ ft. per min., which is about the maximum at which it would be safe to operate a cast-iron flywheel with no joints. If the wheel is of the built-up type of construction having either flange, pad, or link joints, the safe speed should be reduced by from 30 to 50 per cent depending on the efficiency of the construction.

Utilization of Exhaust Steam

IN THE issue of Nov. 1 on page 1105, E. W. M. asks about the utilization of exhaust steam for his heating system. I see no reason why he should not heat his new office with his exhaust steam. In the first place, I would advise lowering the vacuum pump, if possible, to the level of the return pipe from the building heated. He will also derive better results if he will tap into the suction pipe to the vacuum pump near the pump and connect into it about a ½-in. cold water pipe. In most systems, it is found that the return water reaches the pump only at intervals; between times, the pump valves and packing become unsealed.

By slightly opening the valve of the ½-in. water pipe, water enough will always be available to seal the valves and maintain a steady vacuum. I would advise pumping the returns into a small tank or receiver located 15 or 20 ft. above the feed water heater, and let it flow from there by gravity into the connection at the top of a heater. It is best, if there is a pressure in the heater, to drop the pipe from the overhead tank 5 or 6 ft. below the connection to the heater and then go up again forming a leg which will always be filled with water which will prevent steam from the heater blowing into the overhead tank. To get the best results from the system he should install on the return connection of each radiation or coil a water seal trap.

In regard to using the exhaust steam for the drying rooms, I think he could use the same coils provided he had sufficient surface, for there would be some difference in the temperature of high and low pressure steam. Some kind of a thermostatic trap should be installed on the return end of the coils, and if the drying rooms are higher than the heater the condensate should return by gravity. I would advise increasing the size of the steam pipe to the coils for exhaust, also making a connection with a smaller live steam pipe so that either one may be used.

Southington, Conn. GEO. H. HUBBARD.

DON'T EXPECT a relief or reducing valve to function properly if it is constantly being tampered with. It should be set, tested periodically and left alone in the meantime.

POWER PLANT ENGINEERING

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Living Standards Are Dictated by Production

In the United States of America, the standard of living is well known to be much higher, on the average, than elsewhere. Of course, we want it to be; but there has to be a reason why it has been possible to achieve this result. Wealth, either from natural resources or the product of man's activities doesn't just happen. It has to be made available. And, unless it is available, it cannot be used to increase the comforts which make a high standard of living possible.

The answer is in our large production per worker, with the consequent high rate of payment to workers which has thus been made practicable.

President Julius H. Barnes of the Chamber of Commerce of the United States points out that in 30 yr. production of steel has risen from 267 T. a yr. to 709 T. for each worker. In 20 yr. the annual output of gasoline per man has risen from 23,000 gal. to 71,000 gal., and the daily output of bituminous coal from 3 T. to over 4 T. undoubtedly this last figure could easily have been much larger had it not been for the unsettled condition of the coal-mining industry and the obstructive influences which have operated to cut down production.

Earnings have increased 100 per cent, then again 200, and still again 300 per cent per worker during the period of this development and these increases have been possible because of the increased production per worker.

This advance has been due, in part, to progress in the intelligence and ability of the workers, but largely to the invention and introduction of improved processes and machinery, which in turn, has meant the greater use of power. Increase in production, increase in earnings of workers, bettering of living conditions always follow increased use of power by an industry, a community or a nation.

Looking ahead, the same rule will apply. If large production, high earnings and comfortable living are to be maintained or advanced, more and more power must be used, and workers must utilize it to increase their output. Wealth which is not created cannot be distributed either as earnings to workers or as payment for the use of saved earnings. Any argument or policy which assumes that creation of wealth can be lessened, yet returns from industry increased, is contrary to possibilities and leads toward industrial disaster. Engineers ought to be among the leaders in spreading the knowledge and conviction of these truths.

The High Cost of Scenery

Almost everyone appreciates wild and rugged scenery, interspersed with water falls, rapidly flowing streams and placid blue lakes nestling in wooded valleys. It is quite a logical outcome of this love for nature that the people have wished to preserve for posterity some of these pictures of nature which for the most part are fading away with the progress of modern industrial life. As a result we have Federal, state and municipal parks and forest preserves.

It is quite unfortunate from a conservation of resources standpoint that these spots where beauty abounds are just the places where water power developments are

possible. So immediately we have a conflict of the aesthetic and the utilitarian.

Recently the people of New York state have been through such a conflict. The Ferris amendment which was submitted to the people in November provided for the erection of hydro-electric plants and transmission lines on not more than 3 per cent of the Adirondack state forest preserve. It was defeated by a large majority.

Apparently the question is settled but actually it is not. As the years go by the conflict will continue not only in this particular case but in many others. It will be renewed because it involves the question of whether a greater service will be rendered to posterity by handing down un-encroached upon beauty with greatly diminished fuel resources or whether modified beauty with conserved fuel resources will be more fully appreciated.

Engineers are lovers of natural beauty just as are those who shout loudest against water power encroachment. Few engineers, however, can listen to the roar of Niagara without a mental computation of its value as a spectacle and its value as a conserver of fuel.

From the engineering viewpoint it would appear logical to weigh the cost of beauty on the one side with the scenic value on the other and attempt a compromise. Certainly it is possible to carry out water power developments without utter destruction of beauty. In fact with careful planning it might be possible to enhance the natural beauty in many developments by the creation of lakes. Even Niagara in the viewpoint of some engineers might be improved by the building of a submerged weir above Goat Island to distribute the flow more uniformly over the entire brink of the falls, at the same time permitting the withdrawal of more water for power purposes.

It would appear that the cost of scenery is high; that wherever possible without total destruction beauty should be utilized and made to lighten the burdens of this as well as future generations.

Architectural Attractiveness in Engineering

In the design and construction of engineering projects the element of architectural attractiveness is too often lost sight of. There is no good reason why a power house or a bridge or any other structure should not be correct architecturally as well as correct from an engineering viewpoint, except perhaps when such structures are located in remote places far away from civilized communities. In the latter case it makes little difference whether a structure is attractive to the eye or not as only few people will see it.

But when these structures are reared in our cities and towns, the element of beauty or at least of attractiveness should not be ignored. It is true, it may cost a little more to make a power house or a bridge attractive to the eye but it will be money well spent. A power plant is too often a blotch on the landscape.

In this connection it is gratifying to note that in building the new Crawford Ave. generating station, the engineers of the Commonwealth Edison Co. have not overlooked the architectural features of the buildings, and in order that the outdoor transmission station which is part of the project, might harmonize architecturally with the other buildings, it has been built of concrete. All outdoor transmission structures had heretofore been built of steel, but after considering the matter, the designers of Crawford decided that steel was out of the question because it lacked the architectural features required to make it harmonize with the other buildings of the project. So it was made of concrete in spite of the fact that the cost of a concrete structure was fully 10 per cent greater than that of a similar steel structure. Other considerations were involved to be sure but the question of attractiveness was the deciding factor. The engineers of the Commonwealth Edison Co. are to be commended for their far seeing attitude in this case, although we have no doubt, but that in the end, the extra expense involved will prove a profitable investment.

Years ago when electricity was more of a novelty than a thing of utility, we thought nothing of making our public thoroughfares unsightly by erecting wooden poles on which were strung large masses of overhead wires. Today our attitude has changed and we not only put the wires under ground where they belong but we make out street lighting fixtures and poles as attractive as we possibly can. This indicates a line of progress in the right direction, and leads us to believe that as time goes on, even the average size power plant will be made an object of beauty—at least it will not be an eyesore.

Are You Burning the Right Fuel?

It is as truly an economic waste of our national resources to burn the wrong fuel as it is to burn a fuel wastefully. A coal burning furnace operated at 65 per cent efficiency when with the same equipment 75 per cent could be realized shows no poorer judgment than to burn coal when an accurate analysis of all costs will show that a saving of 10 per cent could be made by burning oil.

Too often we learn of changes being made from one fuel to another based entirely upon fuel costs delivered to the plant. This, of course, is the most simple comparison to make. It is, however, absolutely inadequate and misleading, in fact it is merely the starting point of a problem which is complex, due, in a great measure, to unstable conditions of the fuel market.

To make a true comparison every item such as fuel and installation costs, labor, cost, fuel handling charges, furnace and equipment maintenance and investment charges must be considered in their full value. As a concrete example consider the replacement of stokers by oil burning equipment. The first question to arise is whether the stokers have been operated to their best advantage. If they have, then what disposal will be made of them when taken out of service. Are you sure you will not want to go back to coal burning when a change comes in the fuel market? That is a pretty hard question to answer. The stokers may be sold to defray a part of the new equipment costs, but if you keep the stokers for future requirements then you must charge operating costs with interest on the stoker investment.

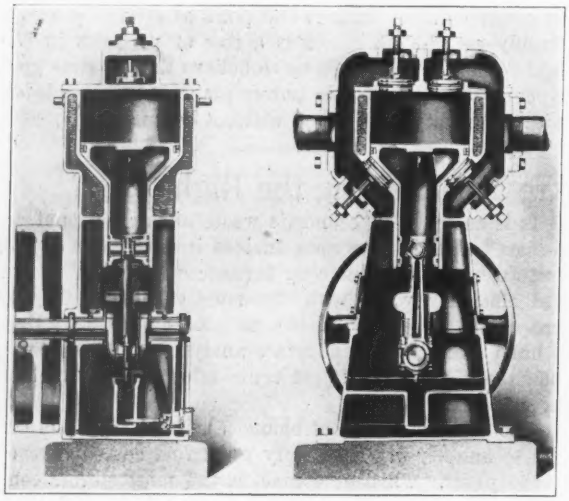
It makes no difference from what angle the problem is approached it is one which resolves itself into a detailed analysis of past investments, present costs and an anticipation of what the future fuel market will bring.

It will, no doubt, pay a great many operators to give contemplated changes more careful thought and study.

POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS

New Line of Small Vertical Vacuum Pumps

RECENTLY a line of vertical vacuum pumps, for use where reciprocating dry vacuums of small capacities are required, has been developed. The pumps are built in six sizes: 4 by 2 in.; 5 by 3 in.; 6 by 4 in., and 8 by 5 in. in the single-acting type, and 10 by 5 in. and 12 by 6 in. in the double-acting type. The single



CONSTANT LEVEL SYSTEM OF LUBRICATION IS USED

stroke pumps are air cooled by means of an annular ring which encircles the cylinder, while the double-acting pumps are cooled by circulating water.

In addition to the standard belt design, shown in the accompanying illustration, each size is built as a self-contained electric motor outfit, using the short belt drive arrangement or driven through pinion and internal gear. The vacuum pump and electric motor of both the short belt and gear driven units are mounted on a metal subbase, so that they are not dependent on the foundation for correct alinement.

The constant level system of lubrication used on the vacuum pumps maintains a constant level of oil, which insures the right amount being distributed to all parts. As in the ordinary splash system, the bottom of the pump base forms an oil reservoir, of sufficient capacity, for the constant-level system. The amount of oil in this reservoir is determined by high and low level pet cocks. Above the reservoir and directly underneath the connecting rod is a constant level pan into which the connecting rod dips and distributes a sufficient quantity of oil for proper lubrication. The constant level pan is replenished with oil from the supply in the crank case by a valveless oil pump operated by an eccentric on the main shaft. Regardless of the amount of oil in the reservoir so long as it is somewhere between the high and low level petcocks, this system will function.

Vacuum pumps of this type are manufactured by the Ingersoll-Rand Co. of New York City.

Metropolitan Section A.S.M.E. Discusses Condenser Tubes

A PAPER by W. R. Webster, vice-president of the Bridgeport Brass Co., on the subject of "Condenser Tubes," was presented before the Metropolitan Section of the A. S. M. E. by the author on the evening of Nov. 8. The paper, which is reproduced in abstract on page 1201 in this issue, brought out a lively discussion in which both users and makers of condenser tubes participated.

Leading the discussion, H. A. Robbins, of the Brooklyn-Manhattan Transit Corporation, said that an experience of 20 yr. had shown no definite conclusions, and that his company was prepared to pass up the problem of making specifications, using in general the U. S. Navy specifications without the navy test. Speaking of mechanical failures, he cited the case of a 40,000-sq. ft. condenser retubed 2 yr. ago, when a large number of tubes were rejected because of such defects. Two hundred of the worst of these were selected for observation and installed. At the time of retubing, which was recently completed, the supposedly unfit tubes had failed to the extent of only 8 or 10 per cent, while the general average for the whole condenser in the 2 yr. was about 40 per cent.

Periodic Cleaning Increases Life

Periodic cleaning of condenser tubes was started by this company in 1909, with a resultant increase in average life of 50 per cent, from 2 to 3 yr. No set of tubes ever lasted 4 yr. in this plant. So far as experience there has indicated, there seems to be no difference in resistance of level or drained tubes to deterioration. Ninety per cent of failures are found due to pit holes, generally forming a row at bottom of tube. On dismantling some old plants 12 or 15 yr. ago, the tubes were found to have stood up very well. Rate of failure depends largely on water conditions, and no cure-all can be found.

A change in the character of failures is obvious as compared with 10 to 12 yr. ago, said E. B. Ricketts of the New York Edison Co. Formerly, tubes would begin to break all the way through from dezincification after a number of years. Apparently the manufacturers have overcome this. Mr. Ricketts said that air bubbles within

18 in. of the inlet end had given trouble on two Waterside condensers in the past 2 yr., although tubes from the same lot had shown no trouble in other machines on both sides of the ones affected, and asked how to prevent this. Mr. Webster recommended the use of iron protective plates, and spoke of an instance where zinc protective plates had given satisfaction for 4 or 5 yr. Stewing in quiescent water is recommended by the Institute of Metals of Great Britain. It would be well to look for leaks in the suction line to condenser. Mr. Ricketts said that tube life ran from 6 to 10 yr., according to the experience of the New York Edison Co., with the average for the past 10 yr. at the lower figure. Early tube failures, he assigned to defects in manufacture not apparent to visual inspection.

Importance of Packing Emphasized

Speaking of the Interborough Rapid Transit Co.'s experience, W. Lawrence cited several instances where apparently unreconcilable differences in performance were observed in groups of tubes from the same lot, placed in similar locations. They pay no attention to draining tubes, and note no ill effect from this. The action of tubes and packing may be of importance, and also the method of packing. It is believed that more attention should be given to kind of packing and building up velocity. Metallic flexible packing is recommended, so that movement will occur at one end of the tubes. Sweeping the walls of tubes with flexible rubber plugs is done about every third night. The average life of tubes in their condensers is between 5 and 6 yr. No research work is attempted beyond observational work on condensers. Replying to a question from the chairman, J. H. Lawrence, the speaker said that the I. R. T. adhered to navy specifications in giving orders for condenser tubes.

In regard to the Brooklyn Edison Company's practice, Mr. Cox said three sizes of tube—¾, 1, and 1½ in. —are employed in their condensers. Failures of the largest size have been practically nil in 5 yr. experience, while the evidence on the smaller sizes is contradictory. The condensers nearest the river seem to have the tubes fail most rapidly. Action near tube ends is perhaps due to churning in water boxes, and the speaker thought that a change in water box design might be desirable.

Copper-Aluminum Alloy Found Satisfactory

W. E. Caldwell, of the United Electric Light & Power Co., cited the excellent performance they have obtained in two condensers having tubes of 5 per cent aluminum and 95 per cent copper, which were installed in 1913 and are still good after giving 56,000 hr. service. A condenser on one side of these two, with Admiralty mixture tubes from the same manufacturer, had to be retubed after 44,000 hr. and another on the other side. in which the tubes were installed in 1921, will have to be retubed after 22,000 hr.

R. J. S. Piggott spoke from experience of both the operating man's point of view and that of the manufacturer. He pointed out the desirability of having tubes mechanically sound, and thought that they should be made as soft as can be conveniently packed, without respect to crystal size in microscopic structure. Anneals for several draws back from the final are now regarded of importance. A uniform percentage of reduction in successive draws seems to be desirable. Air segregation probably does not differ through the length of tubes, but trouble occurs at inlet ends on account of direction and velocities of flow in this region. Only in recent years has attention been paid to form of tube entrance. Round head orifices tend to eliminate the trouble.

Experience of the American Brass Co. was dealt with by Mr. Bassett, who said the corrosion problem was a difficult one, involving much of purely chemical nature. The effect of air is undoubtedly marked. Extensive spray tests are now being undertaken. When supply of tubes to the New York Edison Co. was started, good tubes were supposed to last 2 or 3 yr., and present day life represents an advance by the manufacturers. Aluminum bronze tubes were formerly made by this company, who for awhile thought they solved the problem; but users returned to the Admiralty mixture because failures were rapid when once started and the average life was not much better.

Tubes Should Be Clean When Condenser Is Out of Service

In closing the discussion, Mr. Webster said that, without positive information on the subject, it would probably be better practice, even in the case of a short lay-up, to clean the tubes at the beginning rather than at the end of the idle period, in order to minimize the effect of sludge settling in them.

Mr. Webster said that Monel metal, very good in some cases, is in others no better than brass. Reaming of shell castings has been tried with varying success. It is much easier to cast a good surface against a sand surface than against an iron mould. As to gage of tubes, the thicker metal will naturally resist attack for a longer time, but whether this is in proportion to the thickness is uncertain.

Second Power Show Begins on Dec. 3

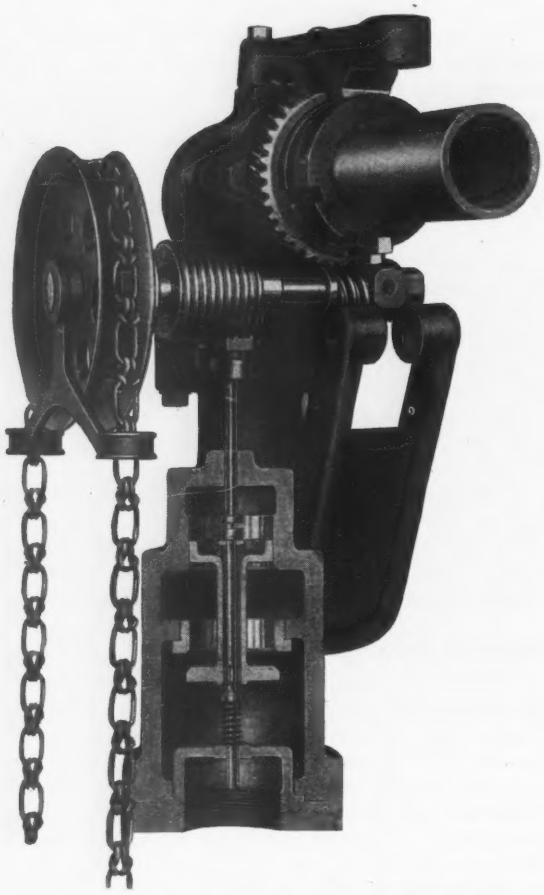
That the second National Exposition of Power and Mechanical Engineering, which will be held at the Grand Central Palace, New York City, is to be even more successful than the one held last year is indicated by the fact that over 250 manufacturers will exhibit apparatus. Last year only the first floor of the Grand Central Palace was used but this year one of the mezzanine floors will also be required.

One of the features of the show last year was the program of motion pictures and this feature will be continued at the coming exposition. The U. S. Bureau of Mines is co-operating with the management and several new films will be shown. The Westinghouse Electric & Manufacturing Co. is supplying two films. One, entitled "The Most Powerful Engine in the World," will show the 70,000-kw. turbine operated by the Interborough Rapid Transit Co. at New York. This machine will be shown during construction and in operation. A second film, entitled "An Electrified Travelogue," will give the history of the development of transportation from the first locomotive down to the present high-powered electric machine.

This exposition is to parallel the annual meeting of the American Society of Mechanical Engineers and the American Society of Refrigerating Engineers, and members of these two bodies are admitted to the exposition on their badge or membership card.

Soot Blower Valve Opens Before Element Moves

IN A soot blower head which has recently been developed the mechanism is so arranged that the element may be set to rotate through a certain working arc with the full opening of the blower valve taking place before the rotation of the element begins. In this way, all parts of the arc of travel are swept with the same effectiveness, the blowing is confined to places desired and no steam is wasted due to the blowing commencing before the working area is reached.



CYLINDRICAL SCREW OPENS VALVE AND THEN ENGAGES SHAFT WHICH REVOLVES THE BLOWER ELEMENT

On the return movement, the reverse is true; the valve does not close until the blower element has stopped revolving.

In operating this head, the hand wheel sets in motion a cylindrical screw next to it which in turn is on a floating sleeve. At the end of this sleeve is a slot equal in width to the plunger of the valve stem. The first thread engages the valve trigger and the valve opens. At this point, the slot engages a driving cog in the drive shaft, sets the shaft in motion, revolves the screw at the right and revolves the head.

During the sequence of operation, the valve stem opens a small valve three-eighths of an inch which permits steam to pass into the top chamber balancing the larger valve and making it that much easier to open.

In making the installation, a metal sleeve is set through the wall and imbedded. To this a face plate is bolted in such a way as to leave the head itself floating to allow for boiler and wall strains. In the face plate, there is another plate kept in place by dip springs. This acts as an air guard and keeps the heat away from the head mechanism.

Practical Refrigerating Engineers Will Meet at Memphis, Dec. 12

DURING the period from Dec. 12 to 15 inclusive, the National Association of Practical Refrigerating Engineers will hold its fourteenth annual convention at Memphis, Tenn. Besides a complete program of technical papers, there will also be an exhibit of refrigerating apparatus and accessories.

Papers which will be of particular interest to the operating man are as follows:

Open Brine Refrigerating Systems, S. C. Bloom, engineer with Atmospheric Conditioning Corp., Chicago, Ill.

High Speed Compressor Valves, J. H. H. Voss, consulting engineer, New York, N. Y.

Internal Combustion Engines in Ice and Refrigerating Plants, A. E. Park, power engineer, Memphis, Tenn.

Evaporating Systems for Refrigerants, W. F. Davis, chief engineer, Lilly Ice Cream Co., Memphis, Tenn.

Railway Refrigerator Car Icing Systems, A. L. Blatti, ass't chief engineer, The Railways Ice Co., Chicago, Ill.

Amount of Ammonia Required for Initial Charges, J. Laichinger, engineer, Pilsbry-Becker Engineering and Supply Co., St. Louis, Mo.

Cooling Water for Ice Making and Refrigerating Plants, J. P. Lawlor, chief engineer with Layne-Central Co., Memphis, Tenn.

Control of Electrical Equipment in Ice Making and Refrigerating Plants, H. P. Hill, vice-president and treasurer, Ophuls & Hill, Inc., New York, N. Y.

Some Causes and Remedies for Cracked and Checked Ice, Erle Ormsby, vice-president and chief engineer, Merchants' Ice and Coal Co., St. Louis, Mo.

Improvements of Ice Plants, R. C. Doremus, refrigerating engineer with Geo. B. Bright Co., Detroit, Mich.

The Operation of the Absorption of Refrigerating Plants, G. A. Pardee, mechanical engineer, Louisville, Ky.

Cold Storage Refrigeration, Chas. W. Chapman, chief engineer, Detroit Refrigerating Co., and Geo. Love, manager, Detroit Refrigerating Co., Detroit, Mich.

Raw Water Ice Making Systems, Van Rensselaer H. Greene, consulting engineer, New York, N. Y.

Safety Movement and Devices in the Refrigerating Industry, M. F. Nicholson, chief factory inspector, Department of Labor, Nashville, Tenn.

Relation of Education and Engineering, Harry Sloan, advisory engineer, Vilter Mfg. Co., Milwaukee, Wis.

Latest Data on Some Common Refrigerants, Wm. H. Motz, technical editor, Ice and Refrigeration, Chicago, Ill.

Burning of Oil Under Power Boilers, R. F. Burke, investigating engineer with Heine Boiler Co., Phoenixville, Pa.

New and Suggested Forms of Ammonia Condensers, Thos. Shipley, vice-president and general manager, York Mfg. Co., York, Pa.

THE LITTLE Tuberculosis Christmas Seal has become familiar to millions of people throughout the United States. It has been largely responsible for the increase in health activities, which in turn have been the means of reducing the death rate from tuberculosis 50 per cent in the past 16 yr.

Many New Power Plants to Be Completed in 1924

THERE is little question that the year 1923 will go down in the history of power plant development as one of spectacular interest. In no other one year have there been so many announcements of new power stations and at no other time have so many radical departures from conventional and previously accepted standards of design been outlined

That 1924 will be an even more interesting year than 1923 is evident when a glance is taken at the list of stations which will be completed during the coming year. A few of the more important stations are shown in the accompanying tabulation.

In addition there is quite an imposing list of industrial plants under construction which are not large in rating but which are fully as interesting due to the special problems involved in their design such as the use of all, or a part, of the exhaust steam for heating or process work.

Work on water power stations will also be quite active during 1924. Many of the projects outlined in 1923 are in the early construction stages, so that 1924 will see the first operation of numerous developments, some of which are of unusual magnitude.

Stoker sales for 1923 will apparently reach the 850,000-hp. mark. While a part of this business is replacement work, the major portion of it represents sales to new plants which have reached the stage where stokers have been ordered or sales which will take care of plant extensions.

Assuming that the boilers will operate at 200 per cent rating this 850,000 hp. of stokers would represent 1,700,000 hp. of steaming capacity which would be sufficient for 3,500,000 kw. of generator capacity, assuming a water rate of 15 lb. per kw.-hr.

SOME OF THE IMPORTANT PLANTS WHICH WILL BE COMPLETED NEXT YEAR

Company	Station	Initial Capacity	Initial Cost	Ultimate Capacity
Brooklyn Edison Co.	Hudson Ave. Station	100,000 kw.	$15,000,000	400,000 kw.
Carolina Power Co.	Brickhaven Plant	15,000 kw.	2,000,000	60,000 kw.
Central Indiana Power Co.	Wabash Plant	40,000 kw.	6,000,000	100,000 kw.
Commonwealth Edison Co.	Crawford Ave. Station	150,000 kw.	15,000,000	500,000 kw.
Connecticut Light & Power Co.	Devon, Conn.	40,000 kw.	4,000,000	100,000 kw.
Consumers Power Co.	Saginaw River Station	40,000 kw.	3,000,000	100,000 kw.
Dallas Power & Light Co.	Dallas, Texas	25,000 kw.	2,180,000	.....
Detroit Edison Co.	Trenton Channel Plant	100,000 kw.	10,000,000	300,000 kw.
Detroit, City of	Detroit, Michigan	80,000 kw.	12,000,000	150,000 kw.
Edison Electric Illuminating	Weymouth Station	60,000 kw.	6,000,000	300,000 kw.
Ford Motor Co.	Ford, Ontario	15,000 kw.	2,000,000	.....
Houston Lighting & Power Co.	Houston, Texas	40,000 kw.	4,000,000	160,000 kw.
Illinois Electric Power Co.	Peoria, Ill.	40,000 kw.	4,000,000	100,000 kw.
Metropolitan Edison Co.	Middletown, Pa.	30,000 kw.	4,000,000	180,000 kw.
Middle West Utilities Co.	Grand Tower Station	50,000 kw.	5,000,000	100,000 kw.
Northern States Power Co.	High Bridge Plant	70,000 kw.	7,000,000	.....
Ohio Power Co.	Philo Plant	70,000 kw.	7,000,000	200,000 kw.
Public Service Electric Power Co.	Kearny Plant	160,000 kw.	20,000,000	300,000 kw.
Tennessee Electric Power Co.	Hales Bar Plant	26,000 kw.	1,500,000	100,000 kw.
Union Electric Light & Power Co.	Cahokia Station	60,000 kw.	6,000,000	240,000 kw.

New Station at Williamsport, Md., in Operation

ONE of the modern power stations recently completed is that of the American Construction & Securities Co., Williamsport, Maryland. The boiler house equipment consists of two Babcock & Wilcox Cross Drum type boilers, each of 1450 hp., for generating steam at 350 lb. pressure with 200 deg. superheat. Ultimately there will be twenty-four such boilers, giving a total capacity of 34,500 hp.

One 14,000 kw. Westinghouse generator is now in operation, but eventually there will be five additional generators at 30,000 kw. each, or a total of 164,000 kw.

Two Link-Belt Clean Water intake screens handle the condenser water for the present and will be added to as the plant enlarges.

After a careful study of the requirements of this installation, the engineers, Sanderson & Porter of New York City, chose the skip hoist as the medium for elevating the coal, particularly on account of the high lift. Coal is received by rail on an elevated track and is either dumped directly into the 50-ton track hopper or dumped from the trestle and stored by a locomotive crane. The present outside coal storage capacity adjacent to the plant is about 5000 T., which will eventually be increased to 60,000 T., when it will be served by a bridge tramway or a long radius locomotive crane.

The balanced skip hoist has a vertical lift of 140 ft., the angle of inclination being 68 deg. from horizontal. With the speed of bucket travel of 200 ft. per min., the hoist has a guaranteed capacity of 150 T. an hour. Under actual test, however, it has exceeded this guarantee. The hoisting operation is continuous, the skip buckets being automatically loaded at the track hopper and discharged in the auxiliary 10-ton overhead hopper. After being crushed, the coal is distributed over the

600-T. storage by means of the 24-in. belt conveyor, being weighed and recorded by the Merrick weightometer.

In the development of this plant the present equipment will practically be duplicated. The entire skip hoist, including the structural steel, was designed and manufactured by the Link-Belt Co., of Philadelphia.

News Notes

OSCAR W. TRUMBULL has resigned the position of general manager of the Metric Packing Co., Buffalo, N. Y., and has been elected vice-president of the Belmont Packing and Rubber Co., of Philadelphia, Pa. He will have charge of manufacturing as well as being identified with sales promotion work.

Mr. Trumbull has had many years experience in the manufacture and sale of packings and rubber goods, having started in this business 23 yr. ago. He was with the Crandall Packing Co., Palmyra, N. Y., for 16 yr. In 1916 he originated the Metric Packing Co., Buffalo, N. Y., and has been the general manager since its inception.

Mr. Trumbull has in mind plans for considerable extensions and improvements of the plant and facilities of the Belmont Packing & Rubber Co.

STATEMENT in the Nov. 15 issue that the Boiler Kote Co., 608 So. Dearborn St., Chicago, Ill., would change its name was erroneous. The company will continue doing business as heretofore under the name Boiler Kote Company.

T. D. CROCKER, who has been assistant to the vice-president of the Northern States Power Co., has been appointed assistant general manager. M. L. Hibbard, formerly manager of the Union Light, Heat and Power Co., Fargo, N. D., becomes Mr. Crocker's successor, and John F. McGuire, manager of the Minot division of the company, succeeds Mr. Hibbard.

FRANK H. SCHUBERT, formerly St. Louis District Manager for the Wheeler Condenser & Engineering Co., and W. G. Christy, formerly with the St. Louis Boat & Engineering Co., have organized the Schubert-Christy Construction & Machinery Co. with offices in the Railway Exchange Building, St. Louis. In addition to representing manufacturers of power plant equipment, the firm will render general construction engineering service and specialize in the design and construction of water cooling equipment for refrigerating and power plants, design of special machinery, process development and construction work.

BABCOCK & WILCOX, LTD., of London, Eng., The Goldie & McCulloch Co., Ltd., Galt, Ont., Can., and The Babcock & Wilcox Co. of New York have organized a new Canadian company to be known as Babcock-Wilcox & Goldie-McCulloch, Ltd., to manufacture and deal in boilers, boiler accessories, pumps, turbines, condensers and other similar products in Canada.

Canadian business of Babcock & Wilcox, Ltd., and of The Goldie & McCulloch Co., Ltd., has been bought by the new company, except the business of the latter company in vaults, safes and safety deposit boxes. Manufacture of its products will be continued by the new company at the works in Galt, Ont., where its head offices will also be located. Branch offices will be maintained in Vancouver, Winnipeg, Toronto and Montreal. R. O. McCulloch will be President, A. R. Goldie, Vice-President, and A. G. Pratt, of New York, Chairman of the Board of the new company.

CONSUMERS POWER CO., of Jackson, Mich., has bought the municipal water and light plant at Durand, Mich. Plans call for making some extensions to the system at this point.

TIME WAS, not so long ago, that a $1,000,000 central station was considered quite some plant. Construction of a substation to cost that sum is an indication of how far we have progressed. The substation will be on the Chippewa River at the south end of Wissota dam and will distribute all the power from the Wissota and Jim Falls plants of the Wisconsin-Minnesota Light and Power Co., 59,400 hp. altogether.

CONSTRUCTION of an auxiliary steam plant to supplement the work now being done by the Chippawa Hydro-electric plant is recommended by the Ontario Hydro-electric Association. It is believed that the Chippawa plant in a short time will have outgrown the demands that are now being made upon it. The Ontario body will take the matter up with Sir Adam Beck. It is contended that at the rate demands are now being made on the Chippawa hydro works municipalities will soon be without the facilities to secure additional power unless steps are now taken.

DR. WALTER E. BOVERI, director of Brown-Boveri & Co., of Switzerland, has been making an inspection tour of the United States. While at Seattle, Wash., he made the statement that the Brown-Boveri Co. expects to establish a factory in this country in the near future. Dr. Boveri has been called the "Steinmetz of Switzerland" and the organization which he represents is similar in its scope to the large electrical manufacturing organizations in this country. This company now has plants in France, Italy, Germany, Austria and Norway, besides the main plant in Switzerland.

PACIFIC GAS & ELECTRIC CO. has awarded the contract for building three 33,000-hp. vertical reaction turbines at its Pit River No. 3 plant to the Pelton Water Wheel Co. These units will operate under a static head of 313 ft. and an average effective head of 280 ft. They will be of materially greater dimensions than any turbines so far installed in the West, the only units comparable with them in horsepower output being for considerably higher heads, and therefore handling smaller quantities of water. Each casing will consist of five pieces, each piece weighing 10 T. or more.

AT THE November meeting of the Plant Engineers' Club of Boston, held at the Boston City Club following the monthly dinner on Nov. 14, Paul Cheever of the Merrimac Chemical Company, of Everett and Woburn, Mass., and Howard A. Arey, of the Naumkeag Steam Cotton Company, of Salem, Mass., led the general discussion on the "Plant Engineers' Club Boiler Code."

AT THE December meeting of the Boston Society of Civil Engineers, to be held Dec. 19, W. M. White of the Allis-Chalmers Company, will give an address on "Hydro-Electric Development with Special Reference to Hydraulic Equipment."